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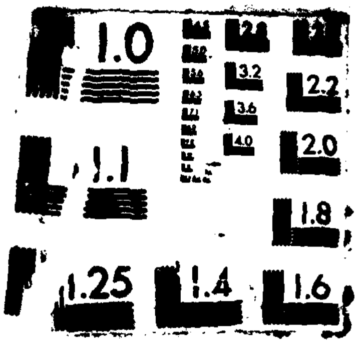
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TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/PM-87/13	A182256	

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
Weather Radar Studies	31 March 1986
7. Author(s): David M. Bernella	8. Performing Organization Report No.
9. Performing Organization Name and Address: Massachusetts Institute of Technology, Lincoln Laboratory, P.O. Box 73, Lexington, MA 02173-0073	10. Work Unit No. (TRAIS) / 11. Contract or Grant No.: DTFA01-80-Y-10546
12. Sponsoring Agency Name and Address: Department of Transportation, Federal Aviation Administration, Systems Research and Development Service, Washington, DC 20591	13. Type of Report and Period Covered: Semiannual Technical Summary, 1 October 1985 — 31 March 1986 / 14. Sponsoring Agency Code

15. Supplementary Notes

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, under Air Force Contract F19628-85-C-0002.

16. Abstract

FAA-funded Doppler weather radar activities during the period 1 October 1985 to 31 March 1986 are reported.

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The FL-2 radar and mesonet units were dismantled, packed, and shipped to Huntsville, Alabama, where the system was re-erected in January and February. The system was checked during February and March and is participating in the joint Cooperative Huntsville Meteorological Experiments (COHMEX) during June, July, and August. The FL-2 system will continue gathering data throughout the 1986 thunderstorm season in Huntsville, Alabama.

Work continued on the analysis of FL-2 data and the comparisons of results with the recent NCAR and NSSL experiments. The development of algorithms for the automatic detection and possible prediction of weather related phenomena also continues. It is planned to have at least microburst outflow and gust front algorithms available for testing during the summer season.

17. Key Words		18. Distribution Statement
weather radar	aviation weather products	Document is available to the public through the National Technical Information Service, Springfield, VA 22161.
low-altitude wind shear	turbulence	
NEXRAD	Doppler radar	
Central Weather Processor		

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	72	

FORM DOT F 1700.7 (8-72) Reproduction of completed page authorized

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WEATHER RADAR STUDIES

I. INTRODUCTION

The principal areas of emphasis for the weather radar program over the period October 1985 through March 1986 have been:

(a) Continued checkout and upgrading of the transportable Doppler weather radar test bed being utilized in a series of experimental programs during 1985-1986.

(b) Data gathering operations at the test bed near Memphis, Tennessee, through November 1985.

(c) Moving of the FL-2 test bed from Memphis, Tennessee, to Huntsville, Alabama, and beginning operations at the new site.

(d) Reduction and analysis of data from the 1983 MIT weather radar experiments and from the Memphis operations in support of the Next Generation Weather Radar (NEXRAD) and Terminal Doppler Weather Radar (TDWR) programs.

(e) Preparation of the weather radar and test bed for the joint COHMEX experiments in 1986.

(f) Analyses in support of the TDWR program.

(g) Development of detailed specifications for certain Central Weather Processor (CWP) products to be generated by the NEXRAD system and support to the Federal Meteorological Handbook committee, and

(h) Planning commenced for operational evaluations of the TDWR products in the 1987-90 time frame in conjunction with the National Center for Atmospheric Research (NCAR).

II. TEST-BED DEVELOPMENT

A. RADOME

The antenna radome is an inflatable dacron bag, 55 feet in diameter and manufactured by Birdair Corporation, Buffalo, New York. The radome is kept inflated by a dual-blower pressure system that is controlled by an external anemometer. The radome was put in service at the Olive Branch, Mississippi, field site in August 1984. Except for an unplanned deflation that occurred in August 1984 as a result of lightning damage to the blower electronics, the radome system has operated very reliably.

In December, the internal pressure was reduced to atmospheric and the bag was crane-lifted off its foundation, repacked into its original packing container, and shipped to Huntsville for re-erection in January 1986. Problems encountered during the folding and repacking operation suggest a different procedure should be used next time the radome is prepared for shipment. Present plans are to fold it only once to approximately 40 feet in length and lash it to a flatbed trailer. This will eliminate the sharp fold creases necessary to pack the radome into its original cubic container format. it is felt that continued sharp creasing will eventually damage the fabric. The bag was re-erected at Huntsville in late January and has been in use without incident since that time.

B. ANTENNA

The 33-foot-diameter parabolic-reflector antenna was designed and built by Hayes and Walsh in Cohasset, Massachusetts. It has a primary illumination from a feed horn designed to yield a 1° circular beamwidth with first sidelobes <-25 dB in the cardinal planes. The dish was first installed at the Olive Branch site in 1984. The antenna has performed satisfactorily since that time. It was removed successfully from its pedestal, disassembled, and packed for shipment to Huntsville in December. it was reassembled on its pedestal in Huntsville in January.

C. ANTENNA PEDESTAL

Antenna pointing is accomplished by a Scientific-Atlanta pedestal that was modified by the in-house Control Systems Group to meet the NEXRAD Technical Requirement (NTR) of $15\ \mathrm{deg/s^2}$ acceleration in both axes, 30 deg/s peak azimuth velocity and 15 deg/s peak elevation velocity. The mount modifications included regearing, forced-flow oil lubrication for the gear box and servo system changes.

The pedestal became operational at the Olive Branch site during the summer of 1984 with final modifications being completed during mid-1985. It, too, was removed from its foundation in December and placed on a flatbed truck for shipment to Huntsville.

Upon disassembly, it was discovered that a shear-pin in one of the azimuth drive couplings was broken. This particular pin has been an ongoing problem since the pedestal was

manufactured some eight years ago. In an attempt to help the problem, the coupler was inverted before installation to provide for more shaft insertion depth. This did not solve the problem and the entire pedestal has been instrumented with strain gauges to aid in further analyzing the fault.

D. TRANSMITTER/RECEIVER

The test bed uses a production line ASR-8 transmitter, on loan from the U.S. Navy, with a Lincoln-developed 'instantaneous' automatic gain control (AGC) receiver. Additional filtering was added to the modulator, in order for the transmitter to meet the objective of an integrated instability residue of less than -50 dB. This equipment was dismantled at Memphis, reassembled at Huntsville in January, and has been operating without incident ever since. In order to reduce contamination of first-trip weather returns by multiple-trip returns, the receiver COHO was phase-shifted pseudo-randomly on a pulse-by-pulse basis. Unphased COHO, used in the system timing circuitry, became a problem when stray components leaked into the receiver and became mixed with phase-shifted COHO. The result is a pseudo-random dc shift at the input of the A/D converters and the appearance of stray frequency components in the transmitter residue spectrum. All efforts to cure this problem have been unsuccessful so far and the phase-switching of the COHO is not presently a part of real-time operation.

E. SIGNAL PROCESSOR

1. Overview

The test-bed Signal Processor (SP) is a Lincoln Laboratory-built system whose basic tasks include AGC normalization, clutter suppression, and autocorrelation lag (0, 1, 2) estimation. The AGC is applied independently to every range cell (800 for first trip processing) for every pulse. Clutter suppression is achieved by the use of a 39-pulse variable coefficient, Finite Impulse Response (FIR) filter producing >50 dB suppression of near stationary clutter. The three autocorrelator outputs are:

$$R_0 \; \alpha \; \sum^{N} |\psi_i|^2$$

$$R_1 \; \alpha \; \sum^{N} \psi_i \, \psi^*_{i-1}$$

$$R_2 \; \alpha \; \sum \psi_i \, \psi^*_{i-2}$$

The number of pulses (N) integrated is approximately the number contained in one beamwidth of scan, which in turn is a function of the scan rate and PRF. The overall architecture of the SP is shown in Figure II-1. The second trip processing has not yet been implemented in the present hardware, although the phase decoder has been designed and built. No functional changes have been made to the SP system during this reporting period.

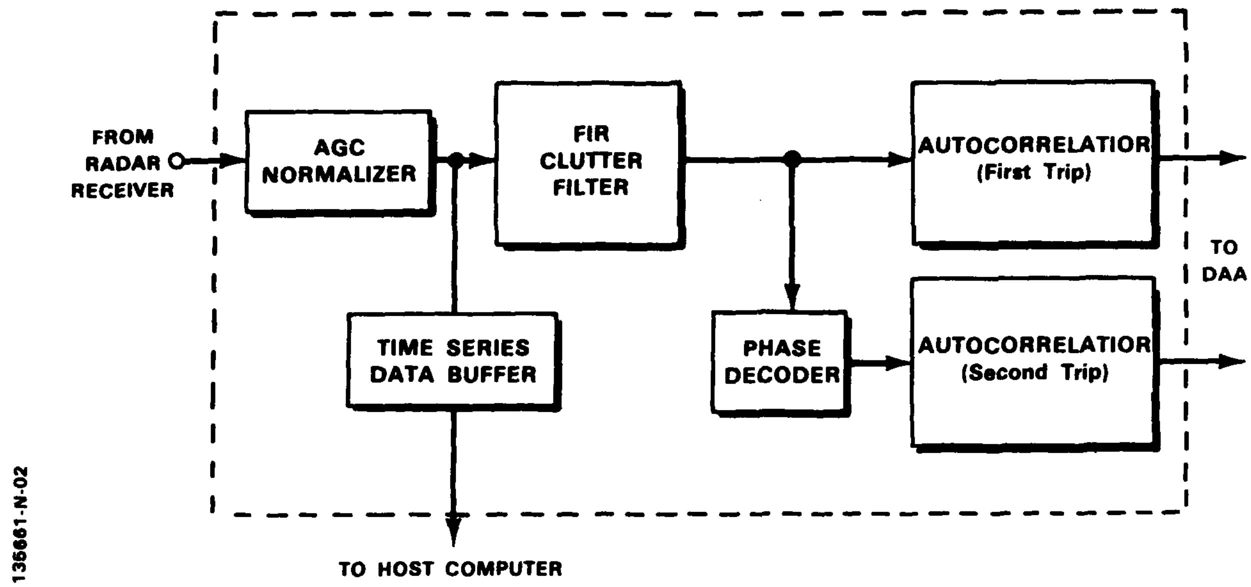

Figure II-1. Signal processor architecture.

Other tasks carried out in the SP include a Pulse Interference Detector (PID), a radar-return signal simulator to produce known inputs to the SP, a Single Gate Processor (SGP) sampler for diagnostic purposes and a phase decoder to provide for decorrelating unwanted second-trip radar returns. A Time-Series Buffer that will allow recording selected data in real time is planned in the near future.

2. Signal Processor Status

A second SP has been constructed and integrated with the development Data Acquisition and Analysis (DAA) processor at the Lexington facility. This unit now provides a facility to check out SP problems and modifications at Lexington. The processor is identical at the test-bed unit, but only has two of the four FIR filter boards implemented. Eventually a full set (4) of filter boards will be constructed.

F. DATA ACQUISITION AND ANALYSIS (DAA) PROCESSOR

1. Overview

The DAA processor is a Lincoln Laboratory-built multiprocessor used to perform real-time processing of Doppler weather radar data. Figure II-2 is a high level block diagram of the DAA architecture. Figure II-3 shows the basic data flow for the data processing modules. Three DAA

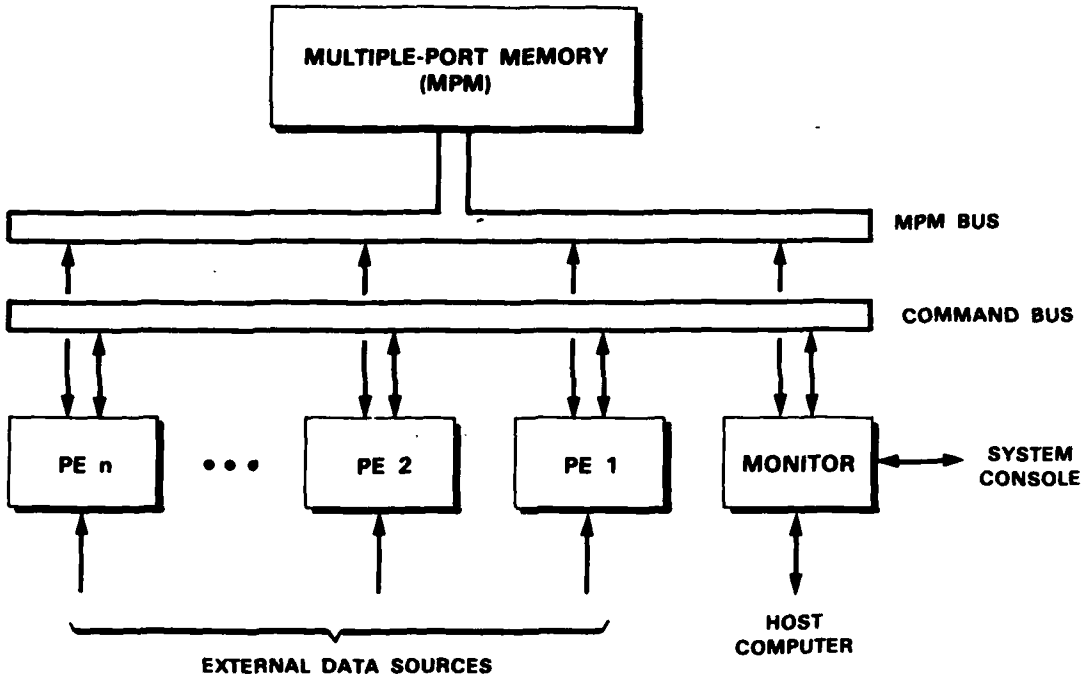

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Figure II-2. DAA processor architecture.

processor systems have been built: one for the weather radar test bed currently being used at the test-bed site, and two at Lincoln Laboratory in Lexington for use as development tools. Hardware and software are developed and debugged using the Lexington DAAs prior to being installed in the test-bed system at the field site.

A major effort during this reporting period was the breakdown and transportation of the test-bed system to Huntsville, Alabama. The DAA test-bed system was disassembled with the rest of the radar system in December. Prior to the breakdown of the test site, DAA modifications were made to the DAA/SP interface to add line drivers and receivers. Compatible interfaces also were added to the SP simulator. A display panel that indicates the status of the Processing Elements (PE) and Monitor boards in the system also was installed and debugged. This panel not only serves as a hardware status indicator, but is also useful for indicating some software malfunctions.

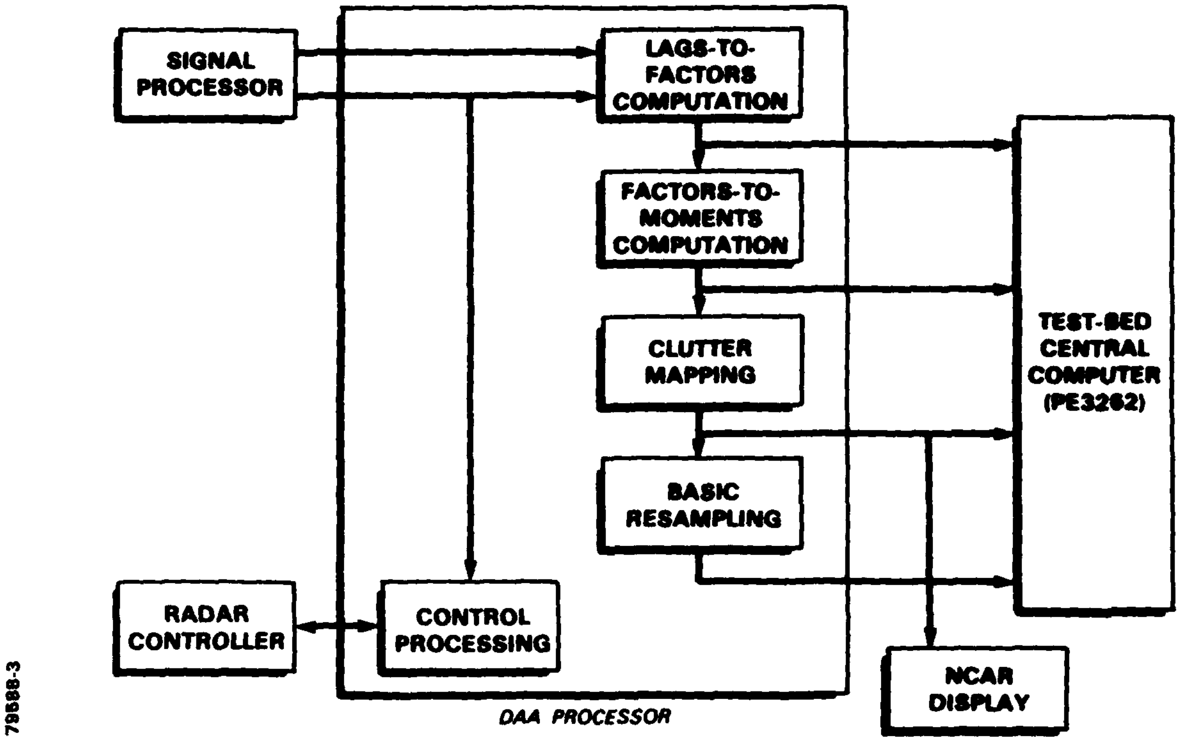


Figure II-3. DAA data flow for basic data processing.

2. Hardware Status

The DAA system at the test site in Huntsville has been completely installed and is fully operational with two PE installed. To fulfill the requirements of the system for first trip weather processing, Table II-1 gives the numbers of each type of DAA hardware module that will be needed.

Table II-2 shows the current status of the DAA hardware modules.

Efforts during this period have been directed towards diagnosing and repairing faulty DAA boards so that the test site system and one Lincoln development system will be able to run the full system software requiring six PE boards each.

One of the problems with four of the PE boards has been diagnosed to be intermittent errors due to cross talk on the boards caused by the 'picture frame' wiring used. Changing this wiring is a major effort, therefore a decision has been made to build four new PE boards. The order for the new boards has been placed, and work will commence in the near future on

TABLE II-1 DAA Hardware Module Requirements					
Type Module	Test Bed	Lincoln Laboratory		Spare	Total
		DAA 'A'	DAA 'B'		
Processing Element	6	4	2	2	14
MDM Control Boards	1	1	1	—	3
MPM Expansion Boards	1	1		1	3
Monitor Board	1	1	1	1	4

fabrication. Several PE boards have been diagnosed to have only minor problems and will be operational in the near future.

The modifications to one multiport memory (MPM) board to update to 256 K RAMs (from present 64 K RAM) have been made and tested. Some design errors were discovered and are being corrected. The MPM boards still are operating at half speed to eliminate intermittent access errors. This problem will be investigated using the new circuit configuration.

Errors in the third Monitor board have been diagnosed and are being corrected. This will allow the third DAA system to be used for hardware diagnosing and modification without impact on software development.

Design of the hardware normalizer preprocessor to be used in conjunction with the lags-to-factors software to improve throughput has been completed. The board has been wire wrapped and is being tested.

Efforts will continue to provide two fully operational DAA systems: one in the test-bed site in Huntsville, and one at Lincoln for development.

3. Software Status

Software development for the DAA has centered around the components needed to support weather data collection and real-time weather data processing. These components include the computation of weather parameter estimates from autocorrelation measurements (from the signal processor), a clutter map, and resampling of polar data to a Cartesian grid. Specific software modules are shown in Table II-3 and described briefly in this section below.

TABLE II-2

DAA Hardware Status

PE No.	Leg	Test Box	Diagnostics	System
TEST LEVEL				
1	All	Passed	Failed	
2	All	Passed	Failed	
3	All	Passed	Passed	Failed
4	All	Passed	Passed	Passed
5	All	Passed	Passed	Failed
6	All	Passed	Passed	Passed
7	HV	Passed	Passed	Passed
8	All	Passed	Failed	
9	All	Passed	Passed	Failed
10	All	Passed	Passed	Failed
11	HV	Passed	Passed	Passed
12	All	Passed	Passed	Failed
13	All	Passed	Passed	Failed
14	All	Passed	Passed	Failed
MPM				
1	HV	Passed	Passed	Passed*
2	All	Passed	Passed	Passed*
3	All	Failed	Failed	Failed**
MONITOR				
1	HV	Passed	Passed	Passed
2	All	Passed	Passed	Passed
3	All	Passed	Passed	Passed
4	All	Passed	Failed	Failed

*Still Operating at half speed

**Ugraded to incorporate 256 K RAMS

TABLE II-3 DAA Software Processing Modules	
Software Module	**Purpose**
Control Processing	Collection and dissemination of control information, handling of CD beacon information
Lags-to-Factors	Calculate autocorrelation estimates from 'lags' to intermediate quantities, 'factors'
Factors-to-Moments	Calculate weather parameter estimates (reflectivity, velocity, spectrum width, S/N ratio) from 'factors' data
Clutter Map	Minimize the display of residual clutter
Resampling	Transform polar tilt data to a Cartesian grid

The DAA software has been upgraded to Version 2.1. These upgrades include utilizing a new Ro (the 'factor' data used to compute signal/noise ratio and reflectivity) format, adding more information to header records, and corrections to ensure even word boundaries for data sent to the PE real-time system. Version 2.1 has been installed and tested in the test-bed system and is working satisfactorily. Version 2.1 provides 'factors' data for recording at up to 6 radials/s operating speed.

Each DAA software module has to operate in "real time." Table II-4 shows the timing constraints for the DAA system.

The worst case timing constraint here requires the DAA to process 37.5 radials/s, while a typical requirement would be 18 radials/s. The present processing capability of each software module timed for utilizing one processing element per module is shown in Table II-5.

a. Lags-to-Factors

Version 2.1 of the Lags-to-Factors code was installed and tested at the test site. Several tests were run to validate performance.

The modifications to enable the module to utilize two PE boards and the hardware normalizer to increase processing speed have been fully designed and coded. These modifications are presently being debugged. Initial timing estimates indicate a processing speed of approximately 31 radials/s should be achieved. This speed will allow the Lags-to-Factors module to process data for a 'typical' data rate.

TABLE II-4			
Timing Constraints			
PRF constrained between 700-1200 pps N pulses averaged for each CPI (Radial)			
CPI/s	$= \frac{PRF}{N}$		
MIN:	$= \frac{700}{128}$	$= 5.5$	Radial/s
MAX:	$= \frac{1200}{32}$	$= 37.5$	Radial/s
TYP:	$= \frac{1200}{64}$	$= 18.75$	Radial/s

TABLE II-5

Processing Element Timing

Processing Module (Utilizing One PE)	Radials/s
Lags-to-Factors (Current)	8
Lags-to-Factors (Hardware Preprocessor)	24
Clutter Map	56
Resampling PPI	25
RHI (Old Algorithm)	33

b. Factors-to-Moments

The Factors-to-Moments module has been fully designed and coded. Several test programs have been written to allow testing of the module in a stand-alone environment. The code is presently being debugged. After full testing in a stand-alone environment, the code will be integrated with the Lags-to-Factors module.

c. Clutter Map

The Clutter Map module has been stable with an ability to process data at the rate of 55 radials/s.

Modifications to include additions to header messages are being implemented.

d. Resampling

The PPI module of the resampling code has been operating successfully with an indicated processing rate of 25 radials/s. A new algorithm for computing the 4/3 Earth approximation has been designed, tested, and debugged. Timing estimates have not yet been verified. The modifications to incorporate the new resampling algorithm to speed up processing rates have been designed and are being debugged. These changes for both the 4/3 Earth approximation and the new resampling algorithm to should enable the RHI resampling to achieve the same processing rates as the PPI.

e. Control Processing

A new version of the 3210 radar control program that provides complete compatibility with Version 2.1 of the DAA software has been installed and tested in the test bed and is operating satisfactorily.

The DAA control processing has been modified to include time tags for each 'Beacons' message report. These changes cannot be fully tested until the hardware has been installed and is functioning correctly.

Efforts will continue to provide software modules that can perform in real time. Initial investigation indicates that with all modifications in place, all of the software modules should be able to provide processing capabilities for at least 'typical' processing speeds.

G. RADAR/ANTENNA CONTROLLER

1. Antenna Controller

The principal objective of antenna control software is to achieve as fast an update of weather measurements as the mount and servo system can handle within the lmitations of acceleration and system bandwidth. The antenna control software for the Scientific Atlanta

mount was completely redesigned including the software to encompass new scan patterns as well as changes in the dynamic response of the mount and the servo amplifier characteristics. This software development has required close interaction between the weather radar project software development personnel and the Lincoln Control Systems Engineering Group personnel who redesigned and implemented the mount analog servo control system.

The Pedestal Control Program is fully operational. Work this reporting period focused on:

(a) an algorithm review,

(b) a coding review,

(c) an attempt to shorten the time required to compile the program.

Algorithm Review: — An algorithm review of the Pedestal Control Program was conducted by means of a presentation to a steering committee made up of all concerned group leaders, system and software personnel. It was generally agreed that the software is handling the hardware properly.

Code Review: — Printouts of all source and documentation files associated with the current (Rev. 3) Pedestal Control Program were provided to a Code Review committee.

Compilation Time: — Compiling the Pedestal Control Program on the PE3210 takes only 3-4 minutes using the Development Compiler, but 2 hours, 35 minutes, using the Optimizing Compiler. The same compilation takes only 1 hour, 17 minutes, on the PE3260 and will take only 38 minutes on the PE3280. In order to take advantage of the faster PE3260 for running FORTRAN VII 0 compilations, all Pedestal Control Program source files have been duplicated on the PE3260. The resulting object file was transferred to the PE3210 via tape.

2. Radar Control — PE3210

A new radar simulator was installed at the test bed. Unlike the previous simulator, the new simulator resides in the signal processor and can be accessed directly through software from the PE3210. Choosing to process simulated radar data instead of actual radar data will no longer require a change of cables. The new simulator is capable of storing up to 256 pulses each of I, Q, and AGC normalization values. Each pulse can contain up to 1024 range gates.

The new radar simulator will enable a comprehensive set of radar system tests and diagnostics to be developed. A group of tests have been identified and incorporated into a test plan that currently is being implemented. Several of the issues that are to be addressed are:

(a) Memory element and diagnostic testing: verify correct operations of the read/write memory elements existing within the signal processor and radar simulator.

(b) Data processing hardware testing: the new simulator will enable test case diagnostics to verify hardware performance. Executing identical algorithms concurrently in software and hardware will enable weak links within the system to be isolated.

(c) Real-time system evaluation: a more general set of system diagnostics will involve loading simulated data into the complete RTS and evaluating the end results that appear on the display monitors.

Item one has been completed and is currently in use at Lincoln Laboratory. The latter two items now are being addressed. Much of the next period will be devoted to developing and integrating the software necessary to test individual hardware elements throughout the real-time system. Work will involve loading the simulator and reading output data from the signal processor and the DAA.

H. MAIN MINICOMPUTER — PE3260

The Real-Time Control Program (RTCP) executes in the main PE3262 minicomputer in the test bed system. The principal functions presently performed by this system are listed below:

(a) Operator Control of:

(1) radar scan sequences,

(2) recording and playback of raw data received from the DAA, and

(3) zooming and panning of the three-moment weather data displays.

(b) Display of:

(1) Cartesian radar map images of weather reflectivity, velocity, and turbulence (the weather spectral moments), and

(2) system status and diagnostic messages.

(c) Processing of DAA raw data for weather product displays:

(1) factors-moments computation, and

(2) polar-to-Cartesian coordinate transformation and resampling.

The two functions in (c) above are interim tasks that eventually will be performed by the DAA.

The RTCP also can be executed in the Annex 2 (AN-2) 3250 minicomputer located at Lincoln Laboratory in Lexington, Massachusetts. A development version of the DAA and a radar simulator also is maintained in the AN-2 computer, allowing software development for both the DAA and the RTCP to be carried out in parallel with data collection operations at the field site.

An analysis of the RTCP and its operation, revealed a number of shortcomings in terms of computer capacity and program capability:

(a) The recording capacity of the 1600-bpi tape recorders was inadequate for recording data at scan rates greater than about 15 deg/s.

(b) The data collection task of the present RTCP would not support increased recording data rates on a faster recorder.

(c) The display task of the RTCP would not keep up with faster scan rates.

(d) The operator control task needed additional control functions and a more flexible status display.

(e) With the above items corrected, the PE3252 will barely keep up with the existing tasks and have no room for future real-time algorithm execution.

To alleviate these problems, it was decided to initiate the following:

(a) Upgrade the computing capability at the test-bed site by purchasing a PE3280 MPS system with 16 MB of memory.

(b) Expand the memory capacity of the AN-2 computer at Lexington to its maximum capacity of 16 MB of memory.

(c) Increase the data recording capacity at the test bed by purchasing 6250-bpi/125-IPS tape drives.

(d) Redesign the data collection and display task in the RTCP.

Progess was made toward these ends during this reporting period.

1. Installation of PE3262 Computer

The problem of inadequate computing capacity was alleviated by the replacement of the existing PE3262 computer with one APU at FL-2 by an interim system consisting of another PE3262 computer with three APUs and 16 MB of memory. This installation was completed at Huntsville in early February, shortly after completion of the move of the FL-2 radar site from Memphis.

This is an interim installation until the new Model 3280 computer that has been ordered from Concurrent becomes available. Nevertheless, that interim system will provide nearly double the processing capacity and double the memory of the previous system. These increases in capacity are essential for implementation of further upgrades to the RTCP.

Unfortunately, installation of the companion field upgrade and memory expansion for the AN-2 RTCP development computer at Lexington has been delayed until the early part of the second quarter of 1986.

2. Upgrade of Genisco Display System

All of the problems associated with the operation of the Genisco color display subsystem that were described in the last status report were resolved successfully by a rewrite of the display generation software. This rewrite was completed in February and the new software was installed

at the FL-2 site in early March. Installation of this upgrade significantly improved the performance of the display system as follows:

(a) All three color monitors now are updated simultaneously rather than sequentially.

(b) The screen update time was reduced from a maximum of 30 seconds to 1.7 seconds.

(c) The new software uses less CPU time but somewhat more memory than the previous display software.

3. Installation of 6250-bpi Tape Recorders

The 6250-bpi/125-IPS tape recorders that were described earlier were successfully installed at FL-2 in mid-March. As a result, we are now able to record nearly four times as much data on one tape reel as was previously possible with the 1600-bpi drives. This is a significant improvement because it reduces both the physical volume of recorded data and the amount of tape handling required by the operators by about a factor of four.

Unfortunately, the new tape recorders did not provide any immediate increase in recording data rate capability. At present, the rate at which data can be recorded on tape is limited by the DAA, in the case of Factors data, and by buffering limitations in the RTCP Recording Task. However, the new tape recorders will be capable of handling the maximum data rates that can be generated by the radar once the required upgrades to both the DAA and the RTCP have been completed.

A redesign of the RTCP data recording task was completed at the end of March and coding and testing are expected to be completed sometime next quarter. Work also was started on designing a new interactive antenna scan control facility that will be integrated with the RTCP and enable the System Operator to update antenna scan parameters and scan sequences on-line in real time.

Hardware and software for the Apollos has been acquired and installed in this respect. At present, however, complementary software for the PE is still under development at the Internet Systems Corporation in Sunrise, Florida. Final acceptance of this software is anticipated shortly. Software for the P.E.s, utilizing Internet-supplied low-level communications routines is being written both for the purposes of acceptance testing for the Internet product and to provide a foundation for future operational software.

The focus of specific software development for the Apollo computers is divided into three main areas:

First, use the color workstation to provide a powerful display capability for the Doppler radar products. In particular, the display is to be highly interactive, flexible, user-friendly, and customizable/programmable. It should be able to plot radar products such as reflectivity,

velocity, spectrum width, etc., aircraft beacon 'tracks,' map information such as runways or county boundaries, and radar range rings. Further, choices about update frequency, the colors employed, the information to be displayed, and the position and size of the displayed images are to be decided by the operators 'on-the-fly.'

To accomplish this goal requires that a variety of display, communication, and data manipulation functions be present. In addition to the display functions mentioned above, a mechanism for automatically transferring radar information from the P.E. computer(s) to the Apollos, a mechanism for maintaining and querying an 'index' of available information and command options, a command structure or 'shell' to integrate the various functions, and additional support functions such as disk maintenance and data compaction/decompaction all must be developed.

Second, use another color workstation at a remote site (such as an aircraft control tower) to simulate TDWR workstation products and functions. This would be an extension of the display capability described above.

Third, use the black and white station as a 'radar control station' where scan patterns could be defined, displayed, and modified interactively. The radar products display is considered to be the most important of the two. No work specific to the radar control area is likely to be undertaken for some time, although the display and communications functions developed for the products display station should be directly applicable.

During this quarter, the following items were accomplished:

(a) Prototype versions of the P.E./Apollo file transfer mechanisms were coded and tested with satisfactory results.

(b) Tests of the low-level interprocess communications between the P.E. and Apollos were completed.

(c) The algorithms that the workstation processes will use have been psuedo-coded and prototype interprocess communications have been designed.

(d) Design of the P.E. processes that will support workstation operations is well along.

The following capabilities will need to be in place by the end of May in order to support the FLOWS COHMEX program during June and July:

(a) Automatic transfer of selected radar images and selected other products from the P.E. to the Apollo.

(b) A rudimentary form of data base to respond to queries by the display process regarding information that has been transferred and is available.

(c) A rudimentary ability to query the above mentioned data base server.

(d) A rudimentary ability to display information.

I. TEST-BED ENHANCEMENTS

A number of modifications were made to the test bed during the first part of this reporting period. Most of these had to do with correcting known 'bugs' in the system or finding and repairing intermittent type problems. Several problems of the latter type were corrected in both the SP and the DAA.

Work continued on the three enhancements described in the last report: the Apollo display/control workstations, increasing the PRF and scan rates, and streamlining the diagnostic and calibration procedures at the test bed. In addition, two more items were added to the list of future enhancements.

(a) a pulse interference cancellation circuit, and

(b) a full capability simulator for system checkout and algorithm testing.

1. Apollo Displays

A small network of Apollo workstations is being integrated into the FL-2 test bed for the purpose of product display and radar control. The network consists of Motorola 68010 based devices: one with an integral bit-mapped color monitor, one with an integral bit-mapped monochromatic monitor, and one monitorless device that will function as a server for mass storage and communications. Current plans call for the color and monochromatic workstations' CPUs to be upgraded to faster, more powerful, Motorola 68020/68881 chip sets.

A substantial amount of effort was devoted to the development of a high-speed communications facility between the token-ring network interconnecting the Apollo devices — denoted DOMAIN — and the PE3262 superminicomputer. This communications facility will be effected via a Transmission Control Protocol/Internet Protocol (TCP/IP) protocol set running over an Ethernet Local Area (LAN) Network. As the types of data to be passed between the Apollos and the P.E. include both weather imagery and status requests, a means must be provided for stream-type (status data) data transfer as well as the transfer of large data blocks (weather imagery).

2. Increase PRF and Scan Rates

The first two steps of the three-step process to obtain higher PRF and scan rates described in the last report[1] were completed before the test bed left Memphis. The Lags-to-Factors recording and processing in the DAA were verified before the radar was dismantled for shipment to Huntsville, Alabama. The dual density 1600/6250-bpi nine-track tape drives were ordered and delivered to the the Huntsville site. There is no longer a basic recording speed limitation due to the tape drives. When the RTCP and DAA speedup is completed, recording will be possible at speeds up to 25 rad/s.

3. Diagnostic and Calibration Routines

No progress has been made on this task during this recording period due to the effort required to dismantle and move the radar to Huntsville. A staff member has been assigned to the task of Data Quality, which will include new diagnostic and calibration routines.

4. Pulse Interference Detector

A circuit was built that will detect and eliminate from both recorded and displayed data large interference pulses from nearby radars operating within the FL-2 RF bandwidth. This circuit compares the amplitude of the receiver output from each range gate with receiver output from the corresponding range gate from the preceding pulse. If the ratio exceeds a preset threshold, the particular range cell is set to zero. An analysis indicated that zero will not corrupt the velocity information and is therefore a good choice. Analyses of the PID impact on clutter suppression are continuing.

5. New Signal Processor Simulator

A new RF simulator circuit that provides realistic I and Q data inputs for system testing was completed, tested, and software to operate it was written. A preliminary set of test signals has been completed and the simulator is operational. Ongoing work will include a larger library of signals to provide a greater spectrum of diagnostic tests.

Other enhancements of the existing RTCP that remain to be completed are:

(a) A redesign and rewrite of the operator interface task to provide more flexibility of control and a more comprehensive status display.

(b) Revision of the scan control strategy to allow dynamic modification and scheduling of radar antenna scan patterns.

(c) Integration of the following algorithms into the RTCP:

(1) Automatic Gust Front Detection,

(2) Automatic Microburst Detection,

(3) Correlation Storm Tracking and Extrapolation.

III. SITE PLANNING AND OPERATIONS

A. MEMPHIS SITE PLANNING

1. Lincoln Radar Site

Preparations were completed and the FL-2 radar was disassembled at the Olive Branch field site. The radar system was packed along with the inflatable radome and sent to Huntsville, Alabama, for re-erection there. Packaging of the teflon-coated fiberglass radome into its original container was a difficult problem because of its heavy weight and slippery surface. The next time the radome is moved, it is planned to strap it down to a flatbed truck. This will eliminate the need to put sharp creases in the radome material and greatly reduce the amount of labor involved.

The Olive Branch site structures and pads were removed by a contractor so that the site can revert to agricultural use.

2. University of North Dakota (UND) Site

The UND site in Mississippi was dismantled in October and the radar tower transported to Huntsville. This radar was re-erected approximately 15 miles northwest of the FL-2 site in April.

3. Mesonet Sites

All stations were dismantled and packed for shipment to Huntsville. All sets at Huntsville are presently in operation.

B. MEMPHIS OPERATIONS

1. Lincoln Radar Measurements

The Fl-2 radar was operational through 27 November, collecting 88 tapes on 12 different days totaling 32 hours and 16 minutes. October and November provided fewer wind-shear events than previous months. A total of eight microbursts and six gust fronts were logged during real time. All of the events occurred on thunderstorm days except for three microbursts on 17 November. On this day, activity developed in response to overrunning as a warm front tracked across the region. There was no convection apparent with this system, and the echo tops were less than 26 kft. Also, the highest reflectivities were prevalent below the 'bright band' (freezing layer).

One of the outflow events on this day occurred just west of the FL-2 site. A peak gust of 9 m/s out of the west over a 5-min period was experienced. This was in agreement with the Doppler field, which portrayed low-level velocities of 10 m/s. The environmental flow before and after the event was calm. Unfortunately, there was no mesonet data collected to verify the microbursts on the 17th.

At least one wind-shear event was detected in each month (April-November) of the FLOWS-85 radar season. Figures III-1 and III-2 present the temporal distribution of microbursts and gust fronts during FLOWS-85. A total of 102 microbursts and 79 gust fronts were noted at the site, either in real time or during playback operations. As shown by Figure III-1, the period from early June to early September provided for 92% of the microburst cases.

The highest daily total was 12 on 24 August. Many of the microbursts occurred in episodes (two days in a row). Five episodes (24-27 June, 15-16 July, 9-10 August, 23-25 August, and 7-9 September) were responsible for 65% of the overall detections.

Two major gaps in the data are prevalent in the late spring and early fall. The latter is due to the fact that this period is characterized by weak frontal passages across the mid-south. It represents a transition from the summertime (air-mass) to fall (cold-front) weather pattern. Hence there were few thunderstorm days from late September to early November.

The lack of wind-shear detections during real-time operations in May arose from certain (unusual) operational constraints during that period. Seven thunderstorm days were recorded during the month. Our attention was typically at higher levels, where NEXRAD1 (UND aircraft) was gathering turbulence measurements. On many occasions, the low-level tilt was not displayed. Also, there were only two continuously operating monitors throughout the month. Velocity information was sacrificed in order to display reflectivity and turbulence and thus be able to guide NEXRAD1 around the strongest cells. In all likelihood, there will be additional events detected once the May tapes are analyzed at the Laboratory. The 28 May case has been processed with at least two microbursts and one gust front not detected during real time.

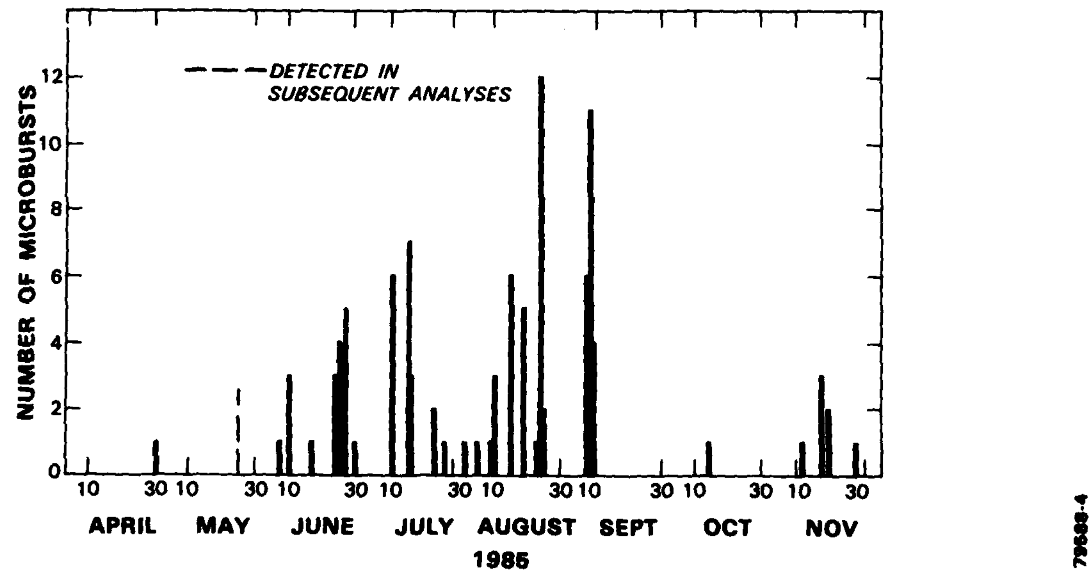


Figure III-1. Temporal distribution of microburst events detected during real-time operations.

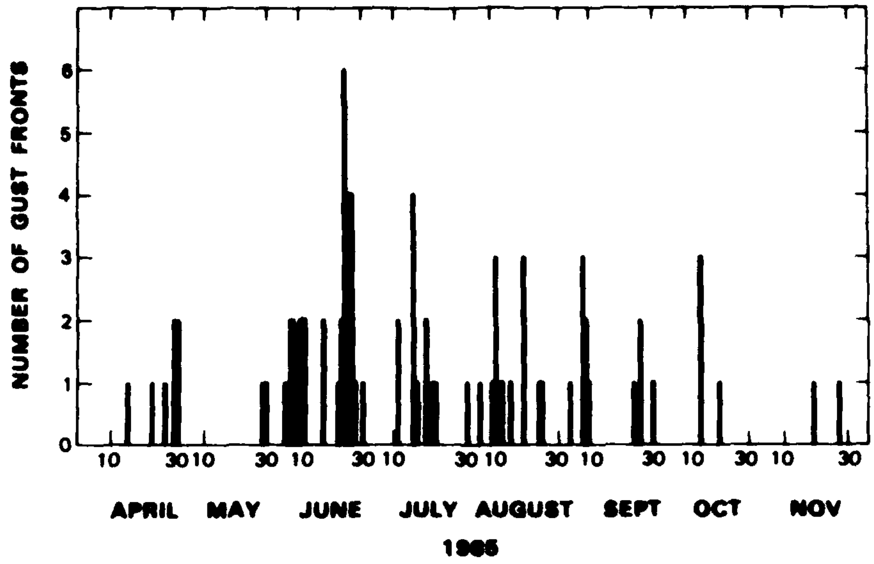


Figure III-2. Temporal distribution of gust front events.

Figure III-2 also portrays a peak of gust fronts in the summer season. The highest daily total was six on 24 June. Each month provided for at least two gust front detections.

2. UND Radar Measurements

The UND radar was not operational in Memphis during this reporting period.

3. Mesonet Operations

The mesonet was operational through the end of October. A problem with the mesonet continued to be noisy high pressure values. By the end of the season, many sensors had drifted 2-5 mb above the network average. At least six transducers exhibited a noise problem, wandering 8 mb over a 30-min period. A new 1986 calibration procedure should eliminate the pressure fluctuations. The strain gauges will be calibrated with temperature effects inherent in the process. They will be allowed 90 minutes instead of 15 to achieve an equilibrium temperature. Then the equations for each sensor will include the variables, temperature, pressure, and elevation above sea level. Several of the sensors were tested at Synergetics in December with the terminals connected to the timer port. This procedure eliminated a 2-mb pressure jump over short time intervals. All the 1986 barometers will be installed in the above manner. Additional testing of the transducers will be initiated after they are calibrated.

4. LLWSAS Operations

Site personnel continued to monitor and change LLWSAS tapes on a weekly basis. There was no loss of data. The LLWSAS system was operational for the entire period and observed several wind-shear events after the mesonet was no longer operational.

C. HUNTSVILLE OPERATIONS

1. Cooperative Huntsville Meteorological Experiments (COHMEX)

There will be three major field programs going on simultaneously in the Huntsville area during June and July. These are: (1) FAA/Lincoln Laboratory Operational Weather Studies (FLOWS), (2) Microburst and Severe Thunderstorm (MIST), and (3) Satellite, Precipitation, and Cloud Experiment (SPACE). While each of these has its own goals and priorities, there will be coordination between them from time to time that will make use of all the resources of the individual experiments to provide as comprehensive a data set as possible for some storm situations. By pooling the resources and focusing on specific storms, we all will benefit from having more complete information than any one program could provide alone.

Planning for COHMEX has been going on for a number of months and has involved investigators from the various cooperating groups at several planning meetings. Figure III-3 shows the geographical layout of all of the FL-2, mesonet, and COHMEX sensors.

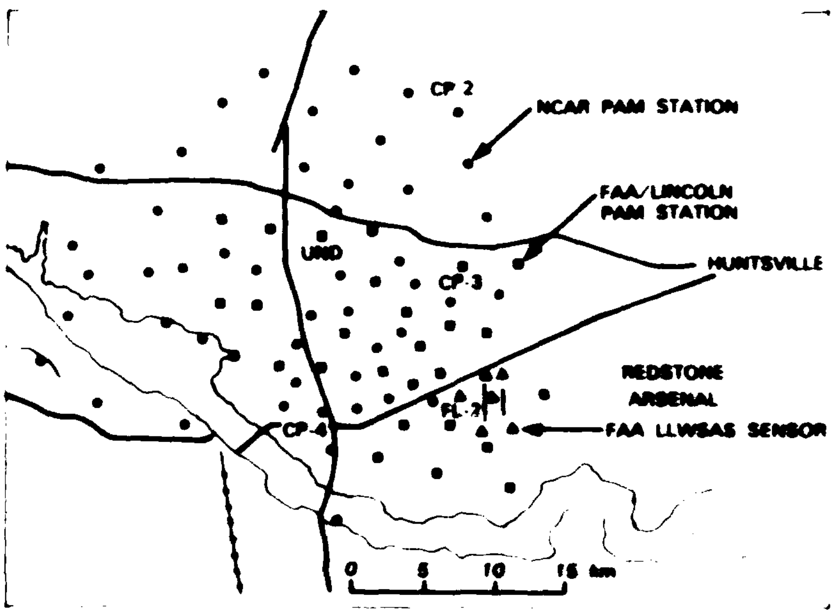


Figure III-3. FAA/Lincoln Laboratory and MIST systems at Huntsville, Alabama

In addition to planning for the collaboration that will take place with MIST and SPACE, we have been planning our own data collection efforts. We already have started our data collection with the FL-2 radar and with the mesonet system. Data collection began early in March and currently is scheduled to continue through the end of September 1986. Emphasis during the 1986 field season is on automated scans in either a Terminal Doppler Weather Radar (TDWR) mode or in a NEXRAD mode.

We are attempting to preplan the decision-making process in such a way that the site personnel can know in any given situation what operation needs to be performed. This includes making the general decision with regard to how, when, and where to scan the radar as well as selecting specific predetermined scans that meet the operational goals. Tables of scan specifications have been sent to the site for use by operations personnel. These will be modified or added to as necessary during the course of the experiment.

2. FL-2 Measurements

Table III-1 presents an overview of site operations during March after the radar first became operational in Huntsville. Twenty-three tapes were collected over a total of 8 hours and 47 minutes. There was only one significant system from which data was gathered during this time: a squall-line on 12 March. Numerous cells displaying moderate to strong rotation were noted throughout the session. A cell at approximately 60 km to our west was responsible for a killer tornado earlier in the afternoon in extreme western Alabama. The FL-2 radar was not operating at this time. There were scattered reports of wind damage in the counties to the southwest, west, and northwest. Huntsville National Weather Service (NWS) personnel inspected the region and found no evidence of a tornado touchdown. The severity of this cell was evident until about 1930 CST when it split into two high Z cores before crossing into Tennessee and weakening.

TABLE III-1

Data Recording Test-Bed Operations in March

Date	Times	Tapes	Weather
12	1610-2030	1-18	Clear/Warm, 77/60 MB, Tornado, Mesocyclone
22	1038-1242	19-20	Clutter/Clear
26	1646-1750	21-22	Clutter/Clear
28	1400-1800	23	Ver 2/Clutter/Clear

The second storm of interest on this day is depicted in the log at 2015 CST. This event presented an azimuthal shear of 46 m/s over 4 degrees. It possibly could have been the mesocyclone that was a precursor to the tornado that damaged Arab, Alabama. At a range of 47 km, it is unlikely that the radar could have resolved the tornado vortex signature in real time. Also, the cell tracked into the FL-2 blanking zone (15 degrees either side of the ASR-7) at the Huntsville Jetport and thus a complete life history is unavailable. However, numerous volume scans of RHIs depicted an overhanging vault, weak-echo trench, and an updraft/downdraft core in association with the cell. The NWS at Huntsville Jetport surveyed the area and reported a damage track of 15 miles caused from this storm.

This system was somewhat unique, since it produced a microburst shear of 25 m/s in the same area as the tornado. The couplet spacing of 1 km presented a radial shear of 25 m/s at 2028 CST. Several gusts of RHIs through this storm depicted convergence/updraft on the forward flank and divergence/downdraft on the rear flank.

3. Mesonet Operations

The FLOWS mesonet became fully instrumented near the end of March. The hardware was installed during the first two weeks of the month while the last two weeks were dedicated to instrumentation checkout. There was only one significant weather system on which we gathered radar data without an operational mesonet. An overview of calibration work and major changes to the system are presented in the following paragraphs.

Most of the 30 instruments required testing and calibration after the 1985 season. The temperature/humidity sensors were shipped to Vaisala for calibration since they had drifted significantly while in the field in Memphis, Tennessee. Most of the wind speed and wind direction instruments were equipped with new bearings. However, many of the units required additional adjustment at the site prior to being installed in the field. The barometers were calibrated in the NCAR pressure chamber during January. New Data Collection Platform (DCP) equations were coded and tested at the site. A major change this year is that only 29 data values out of 30 will be transmitted to the GOES satellite. There always has been one bad minute each 30-min block, since the DCP shuts down while it is transmitting. We will gain additional data for each station such as the power supply voltage, MCM temperature, pressure transducer temperature, and solar panel voltage. New temperature sensors were installed within the styrofoam casing next to the barometer to allow for a correlation between temperature and pressure changes. A new wiring procedure between the pressure sensor and DCP should provide less variability. Testing at Synergetics in December revealed a reduction of up to 2 mbs of fluctuation was attained by this procedure.

The 1986 barometer calibration procedure should provide for more reliable pressure readings. Each set of sensors was allowed a soak time of 90 minutes to achieve a thermal equilibrium. This will eliminate the dynamic pressure fluctuations experienced in 1985. The use of a wide pressure range will minimize additional calibrations if the test bed is moved to a climatically different locale. Preliminary results indicate that a stronger correlation between pressure input and voltage

output was obtained. Each sensor was tested at the site in February with an average error of 7 mbs from the site microbarograph. This is not ideal, but is better than the 19-mb deviation at the beginning of 1985. An additional calibration constant will be determined for each station and included in the software in early April.

Data was gathered at the end of March to ascertain if the software and hardware changes had provided for more reliable pressure readings. Initial analysis revealed that only one sensor varied by more than 0.6 of a millibar over an hour. The spare unit at the site will be installed in place of the questionable unit. There then will be no spare units in case further complications occur this year.

The spatial distribution of mesonet sites is much the same as last year with the sensors generally found to the south, west, northwest, and north of the radar. An average station spacing of 3-5 km will allow the ground instruments to resolve even the smallest outflow. There are several gaps in the network that are designated as NCAR's PAM stations during COHMEX. Geographic grid coordinates, elevations, and sea-level factors already have been determined for each station. The FL-2 site is equipped with a mesonet, anemometer (for the radome), and an LLWSAS within several hundred feet. Wind events in this area can be captured with good resolution.

4. LLWSAS Operations

The Huntsville LLWSAS system became completely operational at the end of the reporting period with the addition of a sixth sensor. However, we were able to obtain several weeks of data with only five instruments fully operational. Site personnel change tapes weekly at the airport Control Tower. A digital readout of each station's wind speed and direction will be monitored on a display in the FL-2 operations room. This will provide scientists with a detailed picture of surface data in the airport area.

5. UND Operations

The UND C-band weather radar became fully operational on 11 June 1986. This sensor will participate in COHMEX operations and then remain in Huntsville to support FLOWS-86 until September when it will be moved back to North Dakota for participation in its winter weather programs.

6. Additional Weather Data

Weather charts and upper-air soundings were available to project scientists early in March. The soundings for four nearby stations, i.e., Jackson, Mississippi; Nashville, Tennessee; Centerville, Alabama; and Athens, Georgia, are obtained each morning from WSI. There will be additional soundings within the study area available at special times. The raw data along with the plotted soundings are archived to assist in post-event analysis. Also, daily surface maps and radar summaries can be obtained from WSI in case the DIFAX charts are unavailable.

A new procedure to obtain daily weather maps was initiated this year. The maps are available via a satellite link from an Alden Micro Earth Station installed on the roof of the FL-2 operations trailer. This system worked properly until a series of power outages at the site in mid-March caused the receiver to malfunction and be unable to acquire the appropriate signals. A new unit was shipped from Alden the following day and has operated since without failure.

In order to receive an RRWDS line, site personnel must dial the desired station. There are no continuous lines dedicated to this purpose yet. Whenever a storm tracks into the area, the appropriate NWS radar must be displayed in order to obtain detailed information on intensity and movement. The RRWDS recorder starts as soon as the data is updated. A KAVOURAS unit is being installed such that we can continually monitor the Huntsville NWS radar. This will provide researchers a complete weather picture in the area for focusing on a narrow sector scan.

7. Clutter Measurements

During this quarter, the FL-2 radar was reassembled in Huntsville, Alabama, and initially calibrated. Following this operation, several subjective and objective clutter measurements were made. The clutter measurements consisted of documenting saturation locations, tabulating radar targets of opportunity, and recording test scans.

The power reflected from a local mountain, Rainbow Mountain, was great enough to saturate the AGC attenuator. The maximum return from the mountain was seen between 30 and 50 degrees from North, at a range of 11 km. The peak reflectivity was noted from the real-time displays as being between 80 and 85 dBz. Greater accuracy of the peak reflectivity will be obtained from the test scans when the recorded tape is analyzed.

Five large fixed targets of opportunity were reported initially. These consisted of two water towers and three microwave towers. They are listed in Table III-2. The reflectivity of the radar targets will be determined from a clutter tape that was recorded in late March and contains these targets.

A total of two clutter tapes were recorded at the test site in March. This data will be used to initially characterize the clutter environment around Huntsville. Clutter measurements will be recorded at regular intervals during the 1986 operations.

8. Additional Support

A strong motivation for FLOWS participation in the COHMEX experiment is the availability of data from many additional meterological sensors in the area. In this section, we discuss briefly the use of instrumented aircraft during COHMEX as well as a distributed ground-based lightning sensor system known as the LLP Lightning Network, which is operated by NASA.

TABLE III-2

Local Fixed Targets — Huntsville Area

Target	Range (km)	Azimuth (deg)
Microwave Tower	5.24	30.5
Microwave Tower	12.21	88.5
Water Tower	2.99	77.5
Water Tower	4.32	299.8
Water Tower	5.68	77.0

Aircraft: — COHMEX will involve several types of instrumented aircraft that are supported by various organizations as shown in Table III-3. Each aircraft will carry a variety of meteorological sensors. The NASA U2 and ER2 are high altitude aircraft that will conduct topside storm measurements using a variety of remote sensing instrumentation such as radiometers and multispectral mapping sensors.

The T-28 is armoured so that it can penetrate thunderstorm cores and collect meteorological data in very intense storm environments. The NOAA P-3 generally will fly in clean air around the periphery of cloud structures in support of microburst research. The Citation and Convair 580 will primarily be making constant altitude storm penetrations in support of FAA turbulence detection studies for FLOWS. The Cessna 207 will be involved in low altitude microburst outflow studies.

Conducting such a multiaircraft experiment requires many issues to be addressed:

- aircraft operations
- scientific and air traffic control coordination
- communications
- surveillance
- resolution of conflicts in flight planes.

The COHMEX experimenters have been holding meetings to address these issues. COHMEX briefings have been held at the FAA Southern Region and Memphis Control Center to identify potential air traffic control problems and work out coordination details.

Lightning Experiments: — The Weather Radar Project has initiated a study to determine whether measurements of cloud electrical activity can provide a useful adjunct to a weather radar in an ATC environment. Emphasis will be on systems that detect and locate lightning since these

TABLE III-3 COHMEX Participating Aircraft	
Aircraft	**Supporting Organization**
UND Cessna Citation	FAA
Convair 580	FAA
NOAA P-3	NSF for University of Chicago
Cessna 207	NSF for Colorado State University
T-28	NASA/NSF for University of South Dakota and School of Mines and Technology
U2	NASA
ER2	NASA

provide large area coverage, have high detection efficiency, have low false-alarm rates and are capable of good positional accuracy. Useful information on local storm development (for example, in the vicinity of airports) might also be obtained from electric field mills and/or field change antennae.

NASA's Marshall Space Flight Center (MSFC) operates an array of four lightning detection and location sensors that cover the area of interest for the 1986 FLOWS/MIST/SPACE experiments. Manufactured by Lightning Location and Protection, Inc. (LLP), the sensors use cross-looped magnetic field antennae to determine the direction to ground strike points for cloud-to-ground lightning strikes. Stated angular accuracy is about ±1 degree. The sensors' electronics analyze signal waveforms to discriminate against intracloud lightning and provide separate detection for each of the return stroke current impulses within a lightning flash. A 'Position Analyzer' at MSFC combines data from the two sensors with largest signal amplitude to determine the time, latitude, longitude, polarity, and intensity of each flash. These data are transmitted over phone lines to remote displays and are recorded at MSFC.

Lincoln Laboratory is working with NASA/MSFC personnel to procure hardware for real-time display of these data in the operations center at the FL-2 site. The display will show recent cloud-to-ground strike locations, color coded according to event time with a geopolitical map overlay. Positive and negative polarity flashes will be differentiated. Our intent is to provide the scientific operators a capability for assessing whether the lightning data adds to the information available from the three-moment radar display, for example, as an index of overall storm 'severity' or as a precursor of storm intensification. If the operator's assessessment warrants, we plan to work with NASA/MSFC on more detailed comparisons of the lightning and radar data in postexperiment analysis.

IV. EXPERIMENTAL DATA REDUCTION AND ALGORITHM DEVELOPMENT

A. PERKIN-ELMER (P.E.) COMPUTER SYSTEMS

The PE3260 and PE3240 computer systems experienced heavy use during this reporting period. While the machines exhibited signs of overloading on occasion, hardware problems were not a limiting factor. In fact, the recent trend toward improved reliability has continued, and hardware problems, serious or otherwise, have become relatively infrequent.

The V-building PE3260 (moved from Memphis after shutdown of the Memphis site) was upgraded with an additional 8 megabytes of main memory, bringing the total to 16 megabytes. The additional memory and the single Auxiliary Processing Unit (APU) have been instrumental in increasing system throughput.

Three STC 6250-bit-per-inch (bpi) 9-track tape drives were delivered during the quarter. One was integrated with the V-building PE3260, while two were integrated with the Annex-II PE3240. These additional tape drives serve two useful functions: to help reduce the tape drive bottleneck in the data processing effort, and to permit translation of future radar data tapes from FL-2 that will be recorded at high density.

The PE3240 formerly in V-building (displaced by the Memphis PE3260) was intended originally for 'batch' processing operations. However, a temporary lack of peripheral equipment has postponed plans for use of that system. Two Fujitsu Eagle disk drives (474 megabytes each) were ordered during the quarter. One disk will be integrated with the 'batch' PE3240, the other with the V-building PE3260.

It was hoped that the Annex II PE3240 might be upgraded to a full 16 megabytes of main memory, which would greatly facilitate real-time system software development efforts. However, it was determined finally that such an upgrade would require the purchase of an extra cabinet and memory chassis, as well as an additional memory controller board. The cost effectiveness of such an upgrade is uncertain, especially when compared to the option of an upgrade to a PE3250 CPU and cabinet, which would support the 16 megabytes of memory in stock form. After issuing an RFI (Request for Information) and receiving a quote pertaining to the two options, a PE3250 upgrade was ordered.

B. SUN WORKSTATIONS

It has been apparent for some time that the P.E. systems were seriously inhibiting algorithm development and data analysis due to:

(a) poor software development facilities,
(b) inadequate file sharing, and
(c) insufficient computation capability (relative to the number of time share users).

A study of the options currently available found that a network of engineering workstations would provide the most cost-effective, near-term solution. Such workstations offer substantial computational capabilities — typically half those of a PE3240 and generally augmentable to twice those of a PE3240. The workstations possess integral, bit-mapped graphics displays that are well-suited to the display and manipulation of the sorts of weather imagery with which the project works. Furthermore, these workstations incorporate a wide range of software tools and programming aids that are specifically intended to assist software development efforts such as those of the project. Finally, these workstations promote the effective sharing of computational and peripheral resources through the use of highly transparent LANs.

Intensive discussions with major vendors and the issuance of an RFI resulted in a decision to purchase a network of engineering workstations from SUN Microsystems, Inc. The selected network consists of 15 monochromatic workstations, 4 hybrid workstations —possessing both color and monochromatic monitors, two servers, approximately 1.9 gigabytes of disk storage and other peripherals. The workstations and servers are all based on the Motorola 68020/68881 chip set. Four workstations, two monochrome and two hybrid, have been designated as public workstations; all others will be devoted to individual group members.

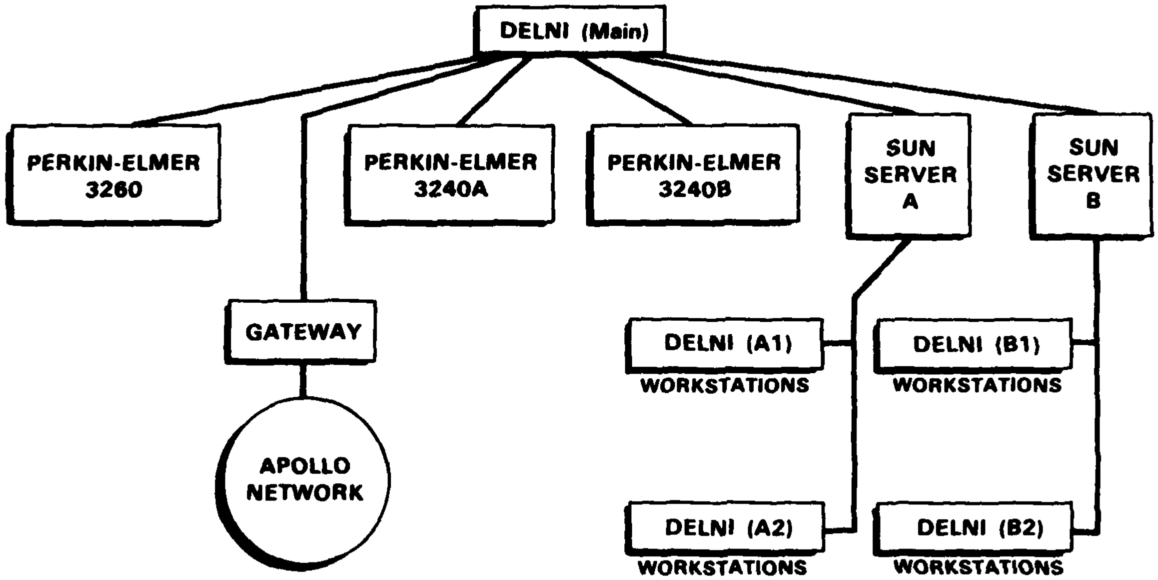
The workstation network is expected to aid productivity substantially in the data analysis and algorithm development areas. The workstation network will be connected to the Lexington P.E.s and Apollo workstations via an Ethernet LAN as depicted in Figure IV-1.

Components of the data analysis SUN workstation network began to arrive in late February. By the end of March, most of the components had arrived and several of the workstations were operating as 'stand-alone' devices. Cabling and ancillary equipment required to implement the network have been installed. The total network should become operational with the arrival and installation of the disk/tape servers. As most of the workstations were purchased without disk drives, the disk servers are prerequisites for the operation of most of the other devices on the network.

The operating system supplied with the SUN workstations is the BSD4.2 dialect of UNIX. This operating system is substantially different from the Perkin-Elmer OS/32 operating system that has been in use by the weather project to date. An arrangement was made with SUN's Lexington Field Office to provide a six-day course covering BSD4.2 UNIX, as well as topics specific to the SUN workstations. The first two sessions of this course were held in late March. It is expected that this course will greatly facilitate the speed with which the SUNs are integrated into the project's data analysis effort.

C. RADAR DATA ANALYSIS

Radar data analysis got started in a more organized manner during this period. The initial step was to prioritize all of the data to be processed according to several criteria. These criteria included the number of microbursts on a given day, the locations of these microbursts relative to the mesonet and relative to the optimum dual-Doppler areas, the number of data tapes collected



79588 7

(1) ALL DISPLAYED CONNECTIONS ARE ETHERNET, EXCEPT FOR APOLLO NETWORK
(2) DIAL UP ACCESS NOT SHOWN
(3) A DELNI IS AN ETHERNET CONCENTRATOR (Equivalent to a Coaxial Cable with Transceivers)

Figure IV-1. FL-2 weather radar/ASR-9 data analysis facility.

on each day, and the number and duration of any gust fronts on these days. The initial priority list included 26 days with 403 FL-2 radar data tapes. As new needs arrive, other days are added to this list, and the order scheduled for processing is adjusted to meet these developing needs. For example, the prioritization according to gust fronts was added to meet a requirement to send data on our gust fronts to the National Severe Storms Laboratory and to the National Center for Atmospheric Research for testing gust front detection algorithms.

There are a number of steps required for the routine processing of our radar data. As a general rule, if a day is scheduled for processing, both the FL-2 and the UND radar data are processed in parallel. The processing steps include the following: (1) translation of the radar data from the real-time format used in the field to a common format used by all data reduction programs, CFT (Common Radar Data Format Tapes), (2) resampling of the CFT data for generating images, (3) photographing or copying these images in hardcopy form. For each of the priority days, these three steps are scheduled as part of the routine processing. When a day has been put on the priority list, all tapes for that day are translated to CFT. The basic routine processing includes resampling of all low-level scans to cover storms at all azimuths out to a range of 96 km, the distance covered by our MODE 1 operations. Currently we are

photographing these using a Dunn color camera on 35-mm film or using the ink jet plotter. The purpose of this base-level processing is to provide a quick-look capability that can be used to determine where more detailed processing is needed.

After the initial processing had been started, we examined the output data to determine if there were any problems in the translation process. Two problems were found that required changes in the translator: one involved a range error of 460 m found in the FL-2 data; the second was that the method used to determine signal-to-noise ratio was judged inadequate.

A signal-to-noise estimator based on all three autocorrelation lags was used. The procedure was changed to the conventional signal-to-noise estimator that uses only the zeroth lag to give more meaningful results. While the results of the translations using the old translator were not noticeably flawed for most purposes, the earlier data were retranslated to eliminate any possible errors.

During the period there was a concerted effort to determine the radar-detectable characteristics of microbursts in the 1985 data from Memphis. The purpose of this analysis was to provide guidance to contractors proposing to build TDWRs for the FAA. The results of these analyses suggest that microbursts in the Memphis area usually were associated with mature but nonsevere thunderstorms that produced moderately heavy rainfalls. The outflows associated with these microbursts were generally less than 1000 m thick and often had leading edges (gust fronts) that were moderately turbulent.

D. MESONET/LLWSAS DATA ANALYSIS

The wind data, which had been continuously collected by the mesonet and LLWSAS networks during 1985, will be compared with Doppler radar data that was collected during thunderstorm activity. The results will be used to (1) confirm Low Altitude Wind Shear (LAWS) and other possible hazardous weather events detected by the radar, and (2) provide an indication of possible undetected wind-shear events. The additional meteorological data collected by the network will be used to diagnose the relationship between temperature, pressure, relative humidity, rainfall, and winds during these events and thus to gain a better understanding of the causes and circumstances of low altitude wind shear.

A software package consisting of various programs to process and analyze mesonet and LLWSAS data has been further refined and implemented. The data from both mesonet (30 stations) and LLWSAS (6 stations) is translated into a Common Instrument Data Format (CIDF). By the end of March, translation of both mesonet and LLWSAS data into the CIDF format had been completed for all of the data collected in Memphis during 1985.

Having translated mesonet and LLWSAS data, we have begun the search for microbursts. An algorithm formulated by Ted Fujita for detecting microbursts at the surface, using only mesonet and LLWSAS data, has been implemented using the 1985 data set as input. This algorithm has been run on the data from February through mid-October 1985. Plots containing meteorological information on these detected microbursts are being generated and analyzed. This

process will provide a means to determine the validity of these microbursts. This analysis procedure has progressed through the data up to August 1985.

It has become evident that the Fujita microburst algorithm (which uses only single station time series to detect microbursts) produces a large false alarm rate. To alleviate this problem, a more sophisticated microburst detecting algorithm (Triangular Divergent Microburst Algorithm) that considers the spatial distribution of winds at several stations for a given instant of time is being implemented to work coincident with the Fujita algorithm. This newer algorithm, which was used by Wes Wilson on the NCAR mesonet data, has been coded into a software package. Testing of this algorithm has begun.

A plotting program that was designed to aid the meteorologist in analyzing the FLOWS mesonet data has been further improved by expanding its present cababilities. This program initially was written for the purpose of plotting wind speed and direction over the entire mesonet area. In late 1985, this program was given the additional capability to plot rainfall rates, and, during the first quarter of 1986, several other meteorological parameters were added to the plotting routine. These parameters are: filtered pressure, equivalent potential temperature, relative humidity, average and peak wind speed, and direction.

E. LOW-ALTITUDE WIND-SHEAR (LAWS) DETECTION ALGORITHM DEVELOPMENT

The low-altitude wind-shear (LAWS) detection algorithm development effort is aimed at producing an automatic procedure for recognizing hazardous wind-shear events from Doppler weather radar measurements. Preliminary real-time algorithm testing will take place during the 1986 experiment at Huntsville, with a major real-time operational demonstration scheduled to be held in Denver, Colorado, during 1987/1988.

Figure IV-2 illustrates the general approach taken to the detection problem. In this approach, several feature extraction algorithms examine the radar observables attempting to locate specific signatures that are characteristic of microbursts. The extracted features then are combined to form final decisions on the absence or presence of hazards. The low-altitude features (divergent outflow, reflectivity maxima, etc.) are available in both on- and off-airport siting scenarios, and are directly linked to the actual hazard to aviation. The upper altitude features (rotation, convergence, sinking core) are only available when the radar is sited away from the region to be protected, and serve more as precursors to the outflow event than as an actual indicator.

The divergent outflow feature extraction algorithm has received most attention to date. It is the primary indicator of the presence of microburst wind shear. Figure IV-3 illustrates the operation of the outflow algorithm in its current form. Measurements of radial velocity are first searched to locate regions of generally increasing radial velocity (i.e., divergence) that meet various 'significance' criteria. These radial segments then are associated in azimuth to form two-dimensional regions of shear. This approach is similar to that used in both the NEXRAD

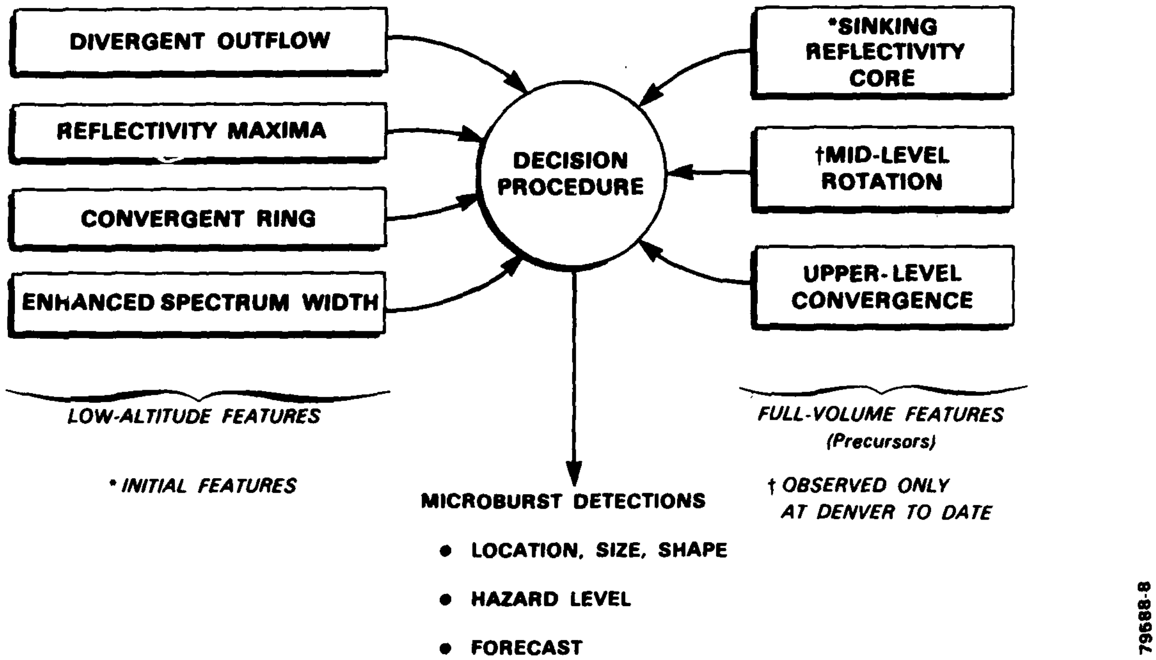


Figure IV-2. General microburst detection algorithm.

divergence and gust front algorithms except that the segment search criteria have been altered significantly. The number of false segments identified by this technique is reduced and results in considerably improved performance.

A trip to the National Center for Atmospheric Research (NCAR) was made in December, to examine and select cases for microburst algorithm testing. Several days were spent on the NCAR radar data analysis system choosing cases from the CLAWS (1984) experiment, and generating magnetic tapes of the data for transport to Lincoln. A total of 4 microburst cases were selected, based on the extent to which the events were unobscured by clutter and the classic microburst precursor features were present. These cases are being translated into the Lincoln internal data format, and subsequently will be used to evaluate performance of the divergent outflow and reflectivity precursor detection algorithms.

The divergent outflow algorithm has to date been applied to a number of microburst and nonmicroburst cases from the 1982 JAWS (Denver) and 1985 FLOWS (Memphis) projects. The results have been generally good, with most microbursts being detected during their mature stages (if not at the onset), and with relatively few false alarms. A tally of the algorithm performance on selected cases from JAWS are given in Table IV-1.

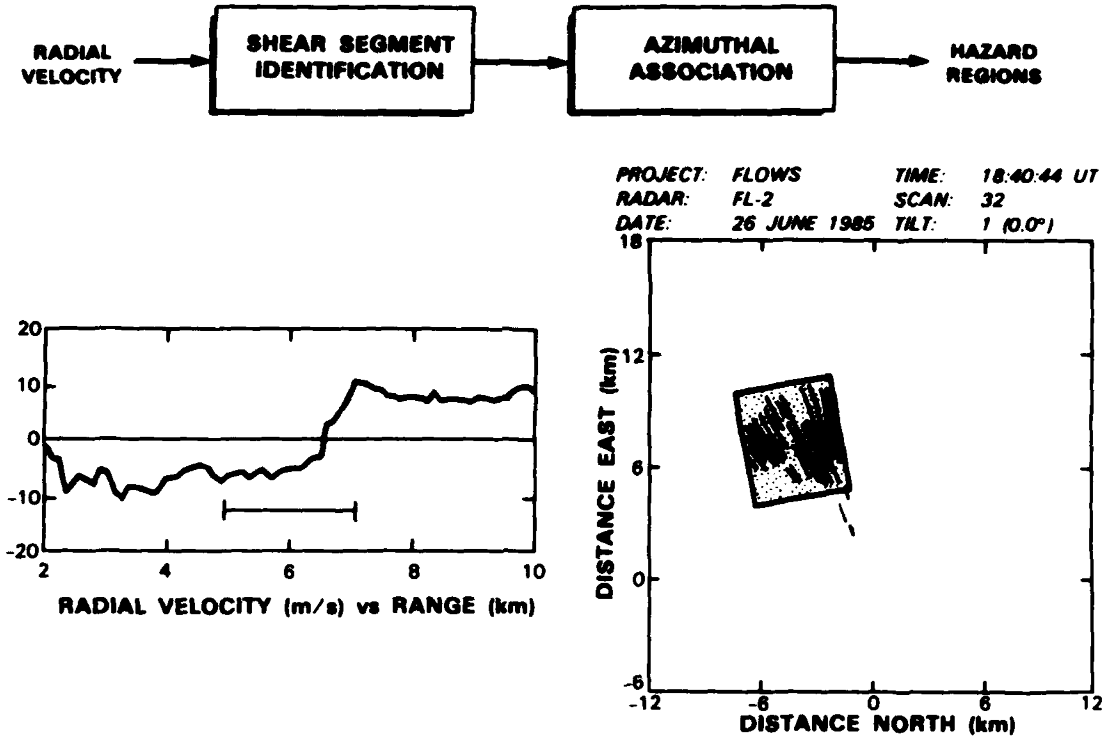


Figure IV-3. Divergent outflow detection.

Additional cases are being studied to obtain a more comprehensive understanding of the behavior of the divergent outflow algorithm. Interaction with researchers at NCAR has been initiated to obtain more in-depth analysis of the results for these JAWS cases. The end result of the Lincoln/NCAR interaction will be a set of test cases with agreed 'truth' information. This ground truth information will allow objective characterization of algorithm performance in the future.

The basic design for a reflectivity feature extraction technique was developed this period. The technique identifies significant storm cell regions, based on local maxima in the reflectivity field. In contrast with previous maxima-based storm representations, the new technique identifies the cell characteristics at numerous reflectivity levels, not just a single level. This detailed representation of the storm structure will allow automated reasoning processes to identify the key aspects of the structure and evolution of the cell, which are important in the detection and prediction of microbursts. Figure IV-4 illustrates one such feature — the 'sinking' reflectivity core. Each plot represents the area of reflectivity above 45 dBz in the storm cell as a function of altitude. As time progresses, the descent of a large water mass to the surface is evident. A

TABLE IV-1

Divergent Outflow Algorithm Performance Results —JAWS 1982

Date	Reflectivity (dBz)	Radar	Listed Events	Observable Events	Detected Events	False Alarms	Scans
30 June 1982	45-60	CP2	3	?	2	1	8
		CP3	3	?	2	0	8
		CP4	3	0	0	0	6
14 July 1982	10-25	CP2	2	2	2	1	8
		CP3	1	1	1	0	1
		CP4	1	1	1	0	1
5 August 1982	>65	CP3	3	?	2	0	3
		CP4	3	3	3	0	3

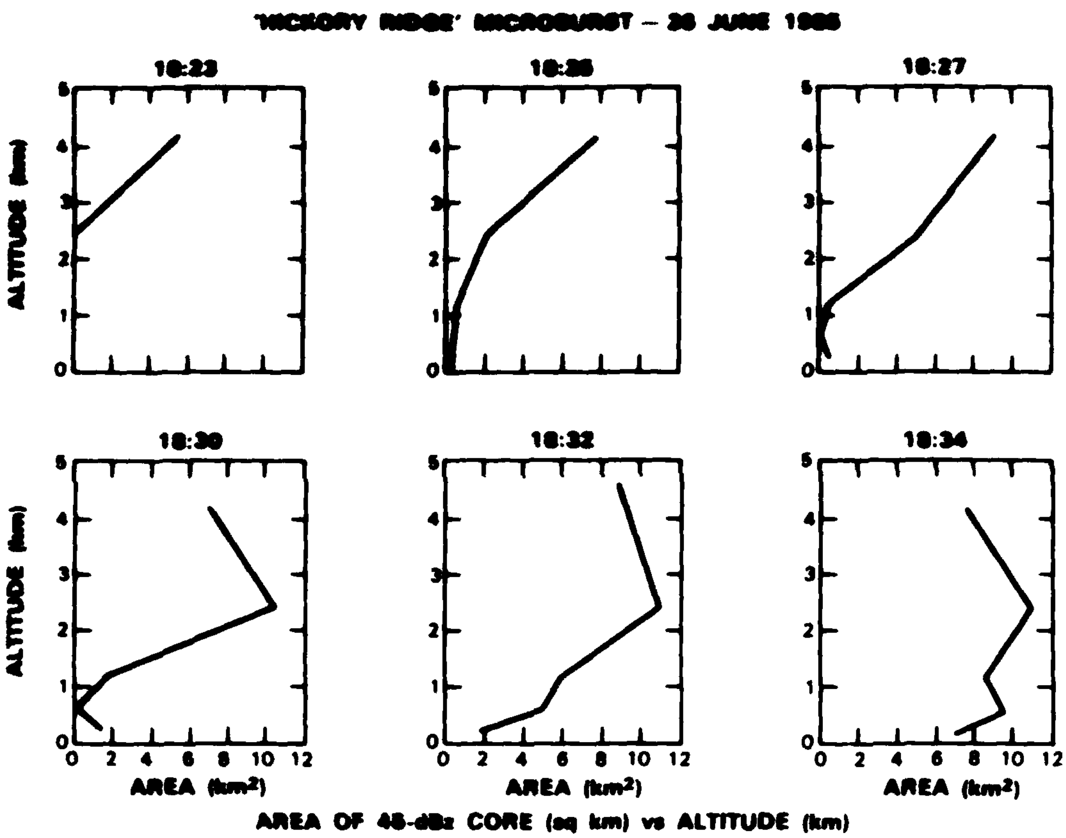


Figure IV-4. Reflectivity evolution precursor.

microburst was generated by this cell at the time of the last plot shown, 18:34 UT (the data is taken from the 'Hickory Ridge' microburst, 26 June 1985). The time-height profile information shown in the figure was obtained automatically using the described cell identification technique. Forthcoming work will focus on the integration of this cell identification technique into the microburst detection algorithm framework, and on the automated recognition of the important structural and evolutionary features.

F. TURBULENCE DETECTION ALGORITHM DEVELOPMENT

The turbulence detection algorithm work is concerned with the assessment of how accurately Doppler weather radar can characterize the turbulent atmospheric environment. In particular, attention is focused on the correlation between the computer results for the turbulent kinetic energy dissipation rate ($\epsilon 1/3$) based on Doppler radar spectrum width observations and $\epsilon 1/3$

computation based on *in situ* measurements using an instrumented aircraft. The Doppler estimates of $\epsilon 1/3$ are processed using the NEXRAD turbulence algorithm together with the layering algorithm required to generate turbulence maps for use by the CWP.

A draft of the project report presenting the results of the 1983 coordinated Doppler weather radar-aircraft experiments in the Boston, Massachusetts, area has been completed and is undergoing review at Lincoln. As stated in previous reports, the data in this report, based on observations of weak storms, shows that light turbulence environments often are reported as severe by the NEXRAD processor. Thus, current and future work will include a more careful assessment of the validity of the underlying assumptions in the turbulence analysis and of the impact of aircraft dynamics on interpretation of the *in situ* measurements. Problems associated with spectrum width estimation also will be investigated.

Work has begun on the analysis of data collected during the coordinated radar-aircraft experiments conducted in Memphis during the summer of 1985. A number of significant software changes were completed for complete processing. Problems associated with spectrum width estimation also will be investigated.

A preliminary look indicates that the Memphis data provides observations of a greater variety of storm types and turbulent environments than did the Boston data. As an example, Figure IV-5 shows the altitude profile of the UND Citation aircraft from the flight on

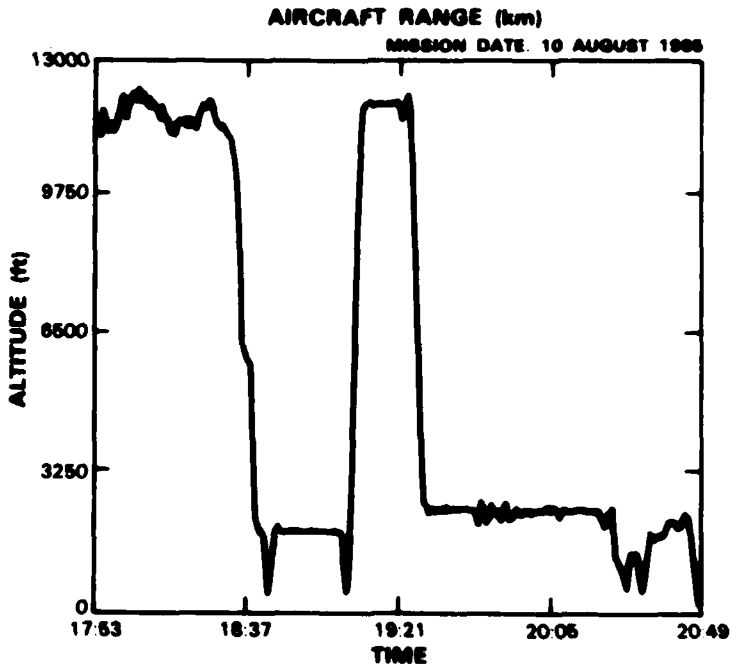


Figure IV-5. Aircraft altitude profiles for UND aircraft on 10 August 1985.

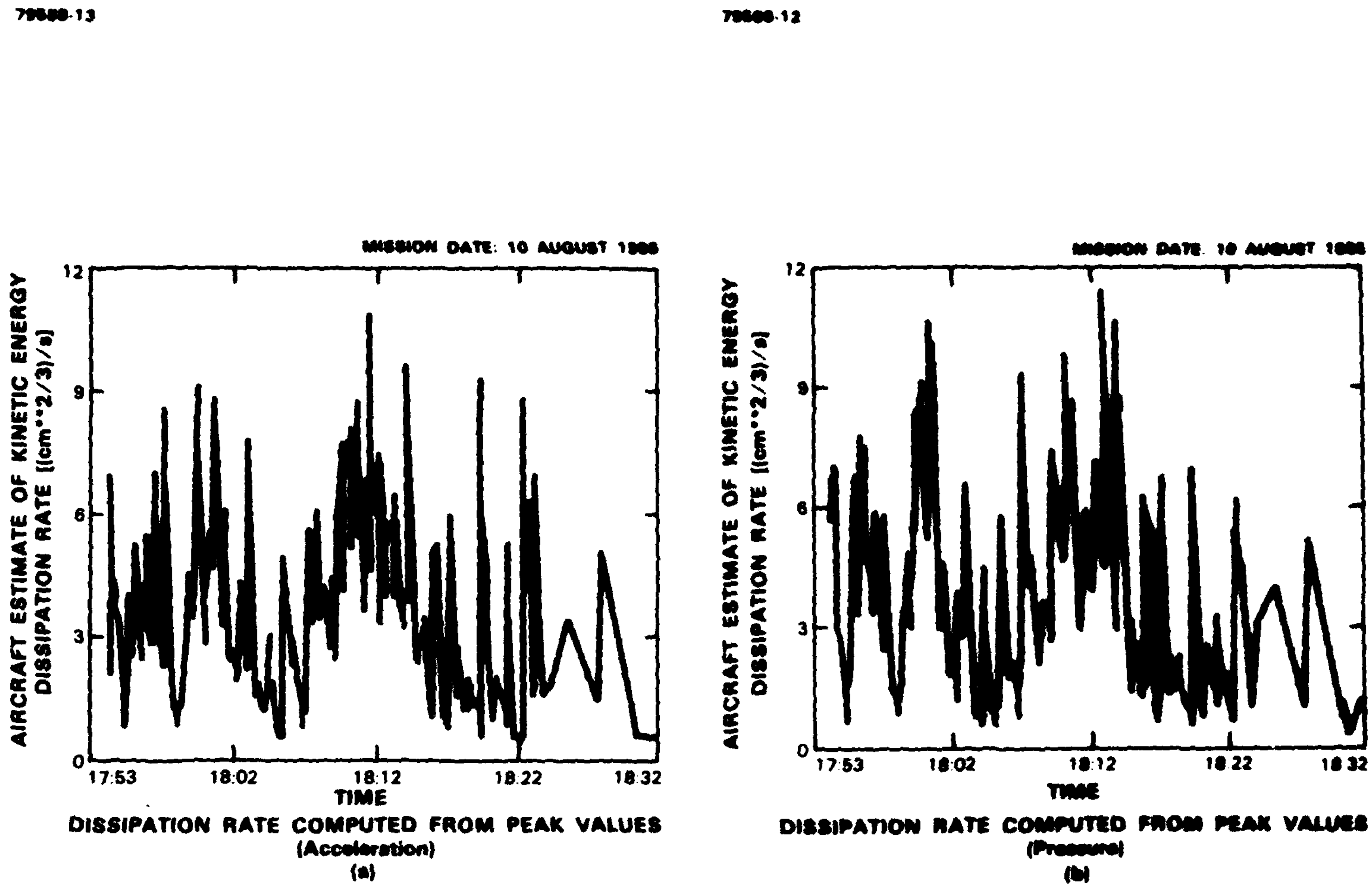


Figure IV-6. Time series of aircraft estimate of kinetic energy.

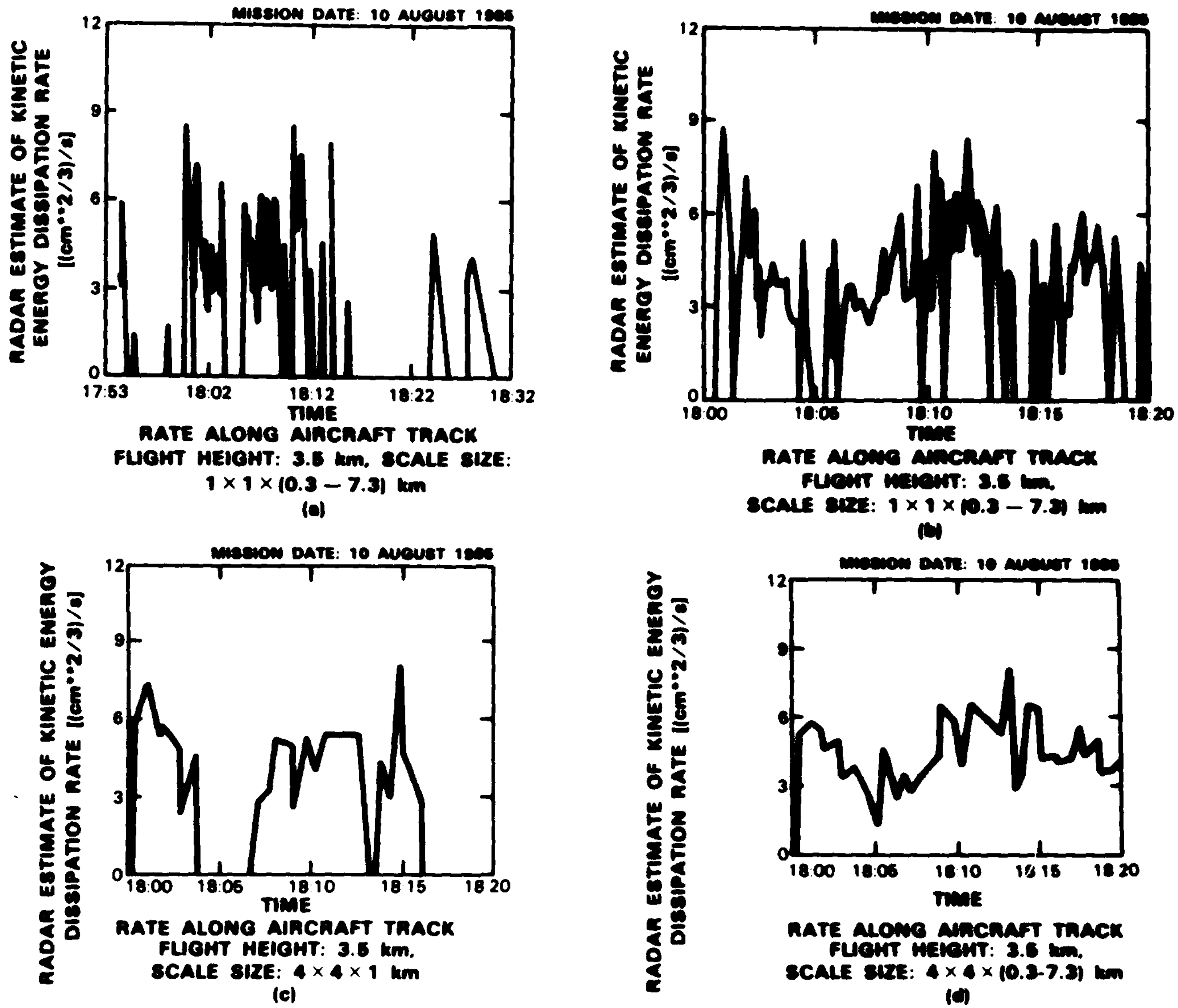


Figure IV-7. Time series of radar estimate of kinetic energy dissipation.

79688-14
79688-16
79688-15
79688-17

10 August 1985. Comparing the four 'constant' altitude segments, it is clear that the turbulence environment, as indicated by the ability of the aircraft to maintain constant altitude, was significantly different for the different segments. Temporal variations are also evident, for example, by comparing the two segments at 12,000 feet. Figure IV-6 shows the time series of computer $\epsilon 1/3$ values associated with the first flight segment at 12,000 feet. Figure IV-6a is based on the acceleration structure function while Figure IV-6b is based on the pressure structure function. As in the Boston data, there is reasonable agreement between these two computational procedures. In contrast to the Boston data, this particular segment indicates much greater short term variability in the turbulence and an overall increase in the intensity of turbulence. Figure IV-7a shows the corresponding plot of radar-based $\epsilon 1/3$ computations using a 1-km-thick layer with a horizontal resolution of 1 km $\times$ 1 km. The radar results show less variability due to the volume averaging. Unlike the Boston 1983 data, the radar does not vastly overestimate the turbulence intensity.

The remaining figures show the effects of increasing the layering volume vertically and horizontally. In Figure IV-7b, the vertical extent of the layer is from 0.3 km to 7.3 km. Vertical layering, in this example, does not significantly change the turbulence levels from those in Figure IV-7a. The horizontal layering over a 4 km $\times$ 4 km region in Figures IV-7c and d tends to smooth the series and extends the indicated periods of higher level turbulence.

It is inappropriate to draw conclusions regarding layering effects at this time. As data from the 22 Memphis flights are analyzed, the impact of layering on defining turbulent region boundaries will become clearer.

G. CLUTTER ENVIRONMENT PERFORMANCE

Effort during this past quarter was focused in two areas. The first was to assess the operational effectiveness of a high pass digital filter in reducing clutter power. The second was an attempt to characterize the analytical performance of a spatial clutter filter that operates on the residual clutter from the high pass filter.

1. High Pass Filter Performance

The high pass filter used in the FL-2 radar system was implemented as a time series finite impulse response (FIR) filter. The filter was designed with a stop bandwidth of 1.5 m/s and a notch depth of 50 dB. This clutter filter was shown to meet the NEXRAD Technical Requirement of >50 dB signal-to-clutter ratio (SCR) improvement for point clutter. It has been shown that the SCR of a moving target simulator signal improved by 50 dB at the Olive Branch, Mississippi, test site when the FIR filter was inserted. The moving target simulator was mounted on a tall radio tower during this test. However, a statistical analysis of data measured with and without the FIR filter over a large area around the Memphis FL-2 site did not seem to reflect the same 50 dB improvement.

The practical impact of the statistical test results are unclear due to many problems that bias the clutter suppression results downward and must be addressed individually before a statistical test can be used accurately to test the operational performance of a clutter filter. The following is a list of problems found in the Memphis clutter data analysis:

(a) low clutter-to-noise ratio (CNR) levels in area used for the test,
(b) sensitivity to clutter limited by clear air returns, and
(c) pulse interference from other S-band radars.

The Olive Branch test site was a benign site in that the clutter levels were, on average, 20 dB lower than representative clutter environments at other airport sites. Because of this, the clutter suppression may have been limited by the CNR. In many areas, the clutter was within 20 or 30 dB of the receiver sensitivity. Therefore, the clutter suppression was limited to 20 or 30 dB. The Huntsville test site has shown much higher clutter returns in certain hilly areas and therefore should provide a better clutter data set.

Interference from another S-band radar also was experienced. This pulse interference showed up in the sidelobes as well as the mainlobe of our radar. These unwanted signals were unaffected by the FIR filter and serve to reduce the apparent clutter suppression. A pulse interference detector currently is being installed and tested.

Finally, returns from moist, warm air were prevalent in the southern areas. Reflections from such precipitation-free wind fields help detect low-level wind shear. On the other hand, these returns impacted the clutter suppression analysis by reducing the dynamic range of clutter, thereby reducing the apparent SCR improvement. This is entirely a clutter analysis problem, and will be alleviated somewhat by making clutter measurements on days with minimal clear air return during the next season.

2. Clutter Map Editor

The second focus of the clutter environment assessment this quarter concerned the analytical performance of a spatial clutter filter. This filter edits the measurements resulting from the high pass filter. Clutter residue measurements during an optically clear day are stored and used to provide spatially variable thresholds during weather data collection operations. After a range sample is taken during normal operations, it is filtered (with the FIR filter), then compared to the corresponding stored clutter residue magnitude. If the sample level is comparable to the clutter residue level, then the sample is deleted.

The explicit assumption made for this editing process is that the spatial extent of the weather phenomena to be detected is such that a number of data points in a given (compact) spatial region can be deleted without substantially degrading algorithm performance. Studies will be carried out in the near future to determine the sensitivity of the microburst and gust front algorithms to missing data. The storm tracking and reflectivity/turbulence layering algorithms utilize data that has been resampled to a Cartesian grid.

Consequently, the analytical performance of the Clutter Map Editor (CME) was estimated by comparing the spatially averaged clutter level in a Cartesian square before and after editing out the largest clutter samples. In particular, we compare the average to the minimum clutter residue within a square.

The expected average and minimum value within a Cartesian square were derived using order statistics and the Weibull distribution (5) as the model for the probability distribution of the clutter residue. The Weibull distribution is described by its median value and a variance parameter, α (when $\alpha = 1$ the distribution degenerates to a Rayleigh and a value of α greater than 1 has a greater variance than expected by a Rayleigh). The S/C improvement versus range for representative values of the Weibull parameter α, using 400 m Cartesian sequences and 120 m radar range resolution, is given in Figure IV-8.

The CME is seen to be very effective at close range due to the small width of the radar samples, which suggests that large clutter sources such as buildings can be edited out easily. At longer ranges, however, the performance drops off until the radar resolution volume ground extent becomes comparable to the area of the Cartesian square. The CME is not effective past this range. Finally, as the Weibull parameter α increases, the CMEs performance increases.

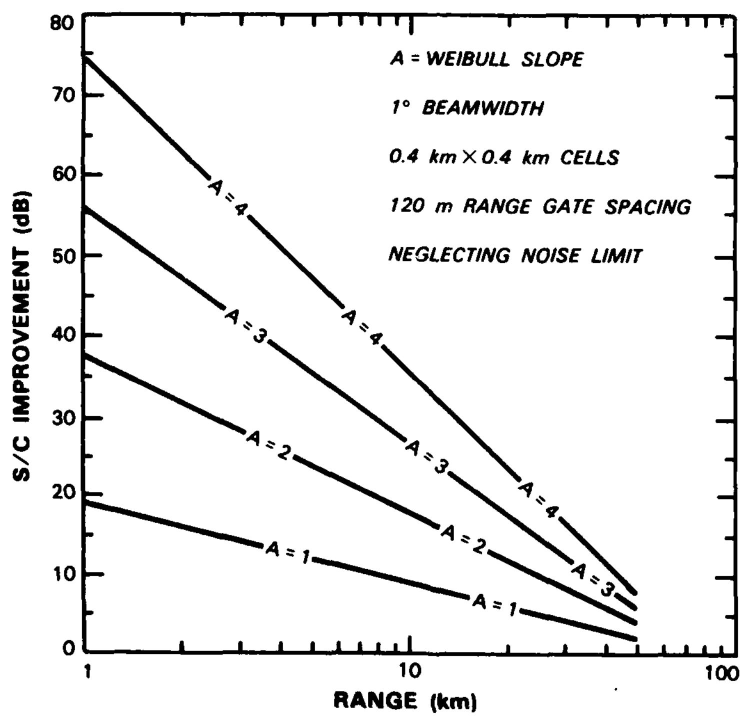


Figure IV-8. Maximum SCR improvement due to CME.

The extent to which the improvements shown in Figure IV-8 can be achieved in practice will depend on:

(a) the actual distribution function of clutter residue,
(b) the spatial correlation between residue levels, and
(c) hardware factors (e.g., sensitivity and dynamic range).

Considerable effort went into developing software to help analyze clutter data statistically. The new software was grouped into three packages. The first package formed a simplistic interface to the CFT software. The second package consists of a basic set of statistical tools including programs to group, distribute, and provide histogram data. The final package was a graphics package. This package plotted standardized analysis graphs and extended the NCAR plotting package by allowing Weibull scaling. These packages were formed to speed the development of specialized data analysis programs during the next data collection season (i.e., mid 1986).

A study of radar data from an operational ASR-8 radar at the Memphis airport commenced. This data was intended to be used as a test case to assess analytically the effect of the CME. Initial analysis suggested that much of the clutter surrounding the city of Memphis could not be improved by a CME. However, a few inconsistencies have been found in this first study, and a more in-depth analysis will be done.

Data reduction and analysis will be the focus of the next reporting period. With the test-bed radar in Huntsville, operational clutter data will be recorded on a regular weekly basis. This data will be used to develop conceptionally a CME strategy followed by a practical development in the future reporting periods. During our clutter study, we also will investigate the following issues:

(a) magnitude of sidelobe clutter,
(b) performance of high pass clutter filters,
(c) saturation levels of clutter,
(d) necessary resolution of the clutter map,
(e) elevation requirements of the clutter map, and the
(f) temporal stability of Huntsville area clutter as well as continuing analysis of the ASR data.

H. GUST FRONT DETECTION ALGORITHM

The gust front detection algorithm development effort is aimed at producing an automatic procedure for recognizing thunderstorm gust fronts and their associated wind shift events from Doppler weather radar measurements. The current focus is on the development of an algorithm that can be tested on the real-time system in Huntsville, Alabama, during the summer of 1986. The algorithm to be implemented is a modified version of the gust front detection algorithm developed at the NSSL in Norman, Oklahoma[2].

The algorithm attempts to identify gust fronts by first locating areas of radial convergence (radial shear segments) from the base radar data (polar format). Segments that demonstrate a large value of peak shear and that are spatially close in the azimuthal direction are combined into a feature. The center of the feature then is computed. Features that lie on different tilts and that exhibit reasonable overlap are combined into a gust front. The feature containing the largest number of radial shear segments is used to represent the gust front. The gust front then is approximated with a least squares curve fitted to the peak shear values associated with the radial segments (Cartesian coordinate system). The gust fronts then are tracked using a second order polynomial in the Cartesian plane. The tracking routine makes it possible to predict future locations of the gust front.

The algorithm has been encoded and currently is being tested by analyzing FLOWS data collected in Memphis during 1985. The algorithm is being developed concurrently at the NSSL and MIT Lincoln Laboratory, and considerable comparison of results will be necessary to ensure a standardized outcome. This will be accomplished through the sharing of data between NSSL and Lincoln Laboratory along with subsequent comparison of results.

The next phase of the project will involve the implementation of a wind shift prediction algorithm to run in conjunction with the gust front detection algorithm. The algorithm currently being considered is the sectorized uniform wind algorithm also being developed by NSSL[3]. The results of this algorithm will be used by terminal aircraft controllers to aid in the runway management decision process. It is expected that the wind shift algorithm can be implemented before real-time testing begins.

The work for the next period will focus on processing the FLOWS data currently available, along with evaluation of the results. At the same time, the sectorized uniform wind algorithm will be implemented and tested. Both algorithms will be modified as necessary, based on analysis results. When it has been determined that the algorithms are generating satisfactory results, a real-time implementation will be installed on the system located in Huntsville, Alabama.

I. RANGE/VELOCITY UNFOLDING

In the event that the FAA TDWR system will operate at C-Band, some form of velocity de-aliasing capability must be incorporated into that system. There are two general classes of velocity de-aliasing schemes. The first class, designated as 'relative de-aliasing', attempts to produce a de-aliased velocity field that locally matches the 'true' Doppler velocity field to within some additive constant. These schemes typically are implemented as software that enforces the conditions of radial and azimuthal continuity on an aliased tilt of velocity data. The second class, designated as 'absolute de-aliasing', attempts to reproduce exactly the 'true' Doppler velocity field through the use of multiple Pulse Repetition Times (PRTs) in the Doppler waveform and modified Doppler moment estimation algorithms (typically implemented in firmware).

Relative de-aliased velocity fields are sufficient for subsequent processing by algorithms searching for shears (e.g., radial shear algorithms and divergent outflow algorithms), as these

algorithms actually examine the first derivative of the velocity field (relative de-aliasing locally preserves the derivative of the velocity field). Absolute de-aliasing may be required, however, by algorithms that attempt to estimate wind direction and speed, such as the proposed gust front/ wind shift algorithm.

The primary challenge for the operational use of a multiple PRT waveform is that of clutter suppression. To date, weather project investigations in this area have concentrated on the use of a staggered PRT waveform in which the PRT alternates from pulse-to-pulse. During the reporting period, the performance of batch PRT waveforms — in which the PRT is alternated over blocks of equispaced samples (two blocks per azimuth) — was investigated. Specifically, the performance of the following clutter suppression scheme was investigated. A data window is applied to each equispaced block of samples, the block is transformed into the frequency domain, the coefficients about zero frequency/velocity are zeroed, and the data then is transformed back into the time domain as an autocorrelation function for the pulse-pair estimation algorithm. Analytical expressions, free of radar dependent values, were developed to characterize the efficacy of various data windows in this respect.

Our preliminary conclusion is that this is a possible scheme, but that meeting a 50-dB suppression requirement will require the generation of a sophisticated data window and also may require an effective passband edge higher than 3 m/s for antenna scanning rates in excess of 10 deg/s.

A presentation was made to representatives from Sperry and Raytheon that detailed Lincoln research and recommendations on the issues of velocity de-aliasing and range obscuration.

J. STORM TRACKING AND EXTRAPOLATION

Reflectivity tracking and extrapolation efforts were concentrated upon two aspects of the Lincoln implementation of the Storm Extrapolation Map (SEM): (1) the addition of functional modules suggested by performance evaluations conducted during the previous quarter, and (2) the development of an improved user interface.

The SEM algorithm evaluated during the previous quarter generated extrapolations in time of radar reflectivity regions by ingesting the LAYER COMPOSITE REFLECTIVITY product (0-24 kft) and tracking information from either the STORM POSITION FORECAST or CROSS-CORRELATION TRACKING (CCT) algorithm. The SEM combines these data to create extrapolated maps through the following four operations:

(a) Storm Identification, in which an input reflectivity field is segmented into contiguous regions of reflectivity above a specified threshold (e.g., 30 dBz);

(b) Centroid to Storm Identification, in which volumetric, mass-weighted centroids from the STORM CENTROIDS algorithm are associated with the regions identified in (a);

(c) Velocity to Centroid Association, in which tracking information from the selected tracker is associated with the centroid/storm pairs identified in (b); and

(d) Storm Displacement, in which an extrapolated map is created by adjusting the velocity-tagged storms identified in (c) for the user-specified extrapolation time interval.

For an arbitrary number of extrapolations forward from a given time, steps a-c need only be performed once; step 4 is performed for each extrapolation.

Extensive testing of the SEM operating in concert with the CCT indicated that the 4-km resolution of the LAYER COMPOSITE REFLECTIVITY product, while desirable for the CCT, was too coarse to support a functional extrapolation capability over the extrapolation time intervals of interest (10-30 min). The manifestation of this in the output of the SEM is that storms would be adjusted to their approximate correct positions in most cases, but would possess positioning errors of one 4-km pixel (excluding cases with intervening convective growth and decay). With regard to the four operations detailed above, the implication is that the CCT tracker information was reliable and steps a-c of the SEM were executed correctly, but the spatial quantization implicit in the LAYER COMPOSITE REFLECTIVITY product prevented accurate positioning of the extrapolated storms.

Since the SEM product is intended only as a planning tool for ATC users, a 4-km resolution for the SEM product is reasonable; and a scheme was developed in which the SEM internally performs its translations at a resolution higher than 4 km, followed by a threshold-based resampling to a 4-km resolution. The intent of this scheme is to provide an SEM product that will approximate most closely the true LAYERED COMPOSITE REFLECTIVITY at the extrapolation time. This enhancement, designated 'High-Resolution Translation', has been implemented and will be evaluated during the first quarter of 1986.

An improved user interface is under development for the SEM. The new interface will provide menu-based interactions with the SEM for the user. The improved interface will be of use both for off-line algorithm development and for the real-time implementation of the SEM at the FL-2 test bed.

Professor Robert Crane's (Dartmouth) subcontracted study is under way. He has been asked to evaluate the feasibility of automatic algorithms for the identification of regions undergoing convective growth and decay. An interim report on his results will be provided to Lincoln in early 1986.

V. USE OF WEATHER RADAR DATA WITHIN THE CENTRAL WEATHER PROCESSOR

The CWP will be the principal system for the distribution of real-time en route hazardous weather information derived from NEXRAD radars to ATC users such as controllers and pilots. Lincoln has worked with the CWP program office for the past few years to:

(a) assess and refine NEXRAD algorithms/products and operational use better to meet the ATC user needs,

(b) define the NEXRAD processing requirements for the CWP, and

(c) obtain feedback from operational ATC users [especially the Central Weather Service Unit (CWSU) meteorologists] on the operational utility and meteorological validity of the products for real-time use by nonmeteorologists.

This support will be sharply reduced in the current fiscal year due to the loss of FY86 funding by the CWP program to finish the tasks that were largely completed at the end of FY85 and to initiate discussion on the nature of an FY87 CWP program in the spring of 1986.

A. FEDERAL METEOROLOGICAL HANDBOOK SUPPORT

The eleventh volume of the Federal Meteorological Handbook (FMH-11) is being prepared to provide the operational guidelines for the operation of the NEXRAD System. The task of writing this document has been delegated to five 'Working Groups' — each of which has responsibility for certain portions of FMH-11 and is comprised of representatives from the agencies developing NEXRAD as well as technical advisors from the NEXRAD Interim Operational Test Facility (IOTF) and institutions such as Lincoln Laboratory. A representative from Lincoln Laboratory is serving on Working Group E (WGE), which has been tasked to write the sections of FMH-11 specifying operational modes, scanning strategies, product mixes, product shedding priorities, and mode selection/deselection criteria.

The second FMH-11 coordination meeting was held in November. At that time, the WGE document was reworked extensively in order to insure consistency among the FMH-11, the NEXRAD Technical Requirements (NTR), and the individual contractor's designs to the maximum extent possible. In order to verify this consistency, WGE has prepared analyses regarding scanning strategy interactions with Doppler moment estimates, RDA data rates, RPG computational requirements, RPG storage requirements, and meteorological surveillance requirements. The current WGE recommended operational modes and scanning strategies, with their primary objectives, are as follows:

Clear Air Mode:

(a) Preconvection Scan — 5 tilts in 10 minutes (5/10)
— earliest detection of precipitation
— wind profiling to four 4 km AGL

(b) Wind Profiling Scan-9/10
- — wind profiling to 10 km to supplement soundings
- — montoring of precipitation onset

Precipitation Mode:

(a) Precipitation/Severe Weather Scan (P/SWS)-14/5
- — volumetric scanning with high update rate and reduced accuracy for volumetric estimates additional

(b) Outflow Detection — P/SWS-15/6
- — P/SWS with an additional low-level tilt at scan's temporal midpoint so as to provide a three-minute update rate at surface

(c) High Resolution — P/SWS-17/6
- — provides nearly contiguous coverage with monotonic elevation sequence for accurate volumetric estimates

(d) Synoptic Scan — P/SWS-9/6
- — nominal scan strategy described in NTR
- — has certain operational deficiencies due to the sizable gaps in the elevation coverage

Figures V-1 and V-2 compare the coverage provided by the P/SWS-15/6 and P/SWS-9/6 strategies. The practical impact of the sizable horizontal and vertical gaps with the 9/6 strategy for the detection of operationally significant aviation weather hazards needs to be determined in the very near future. However, it appears that such studies will not be carried out by WGE or the NEXRAD program office. Lincoln is currently not in position to carry out such studies during FY86.

No changes in the WGE document are incorporated at this point. The next FMH-11 meeting is scheduled for late April 1986. The current WGE membership is: Peter Ahnert (National Weather Service), Major Gary Sickler (US Air Force), Frank Amodeo (MITRE), Marc Goldburg (Lincoln).

B. RADAR WORKING GROUP SUPPORT

Lincoln personnel attended meetings of the CWP Radar Working Group (RWG) in October and November of 1985 and January 1986. This group's work now is focusing on the mosaicking of NEXRAD products from a number of NEXRADs within the CWP as opposed to:

(a) validation of the basic accuracy of the CWP products generated by a single NEXRAD, and/or

(b) assessing the utility of CWP products for real-time nonmeteorologist users,

due to a reduction in the scope of the CWP program. Lincoln's contribution to the RWG had

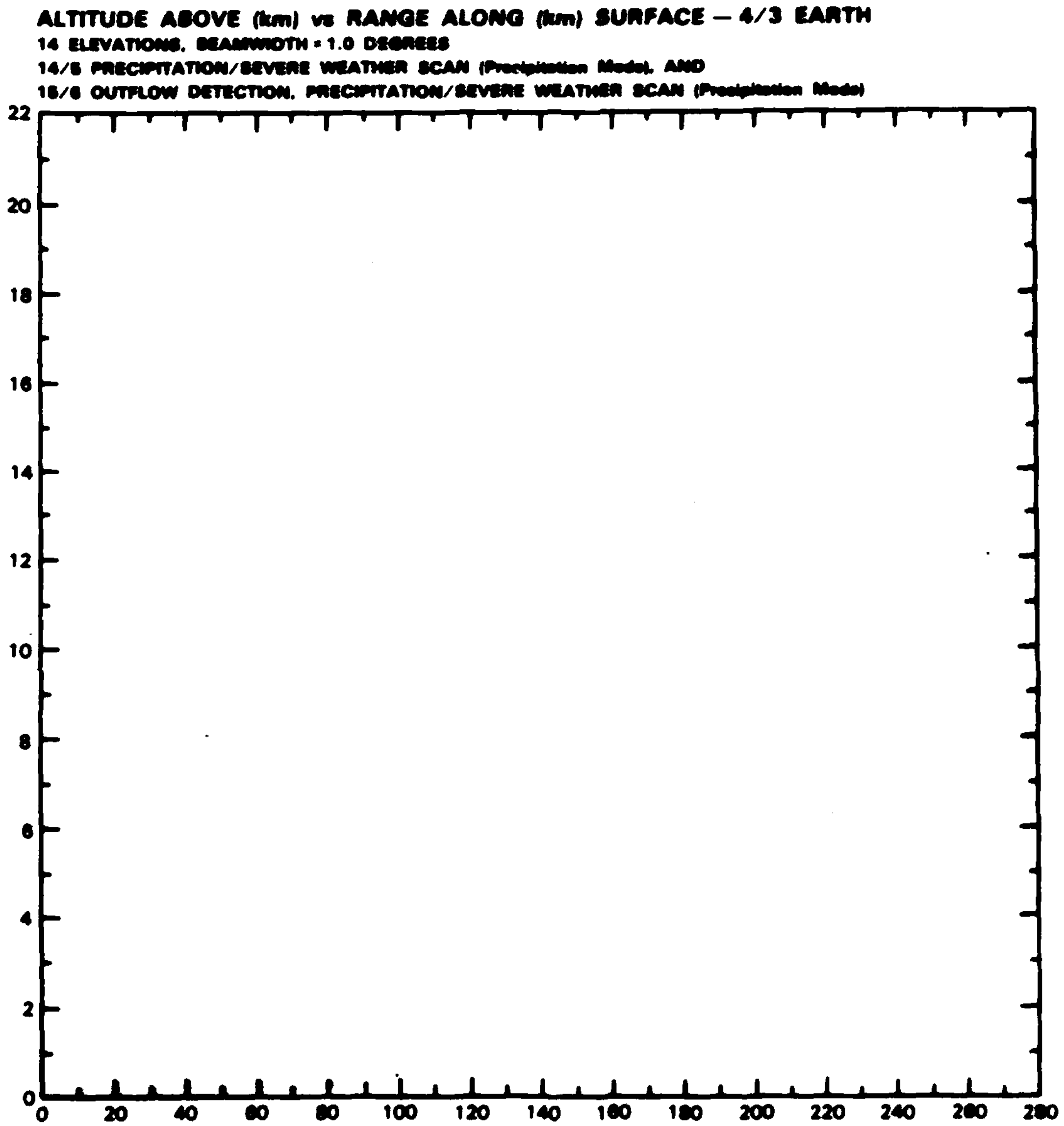


Figure V-1. Coverage provided by FMH-11 Working Group E scan strategy for precipitation/severe weather/outflow detection.

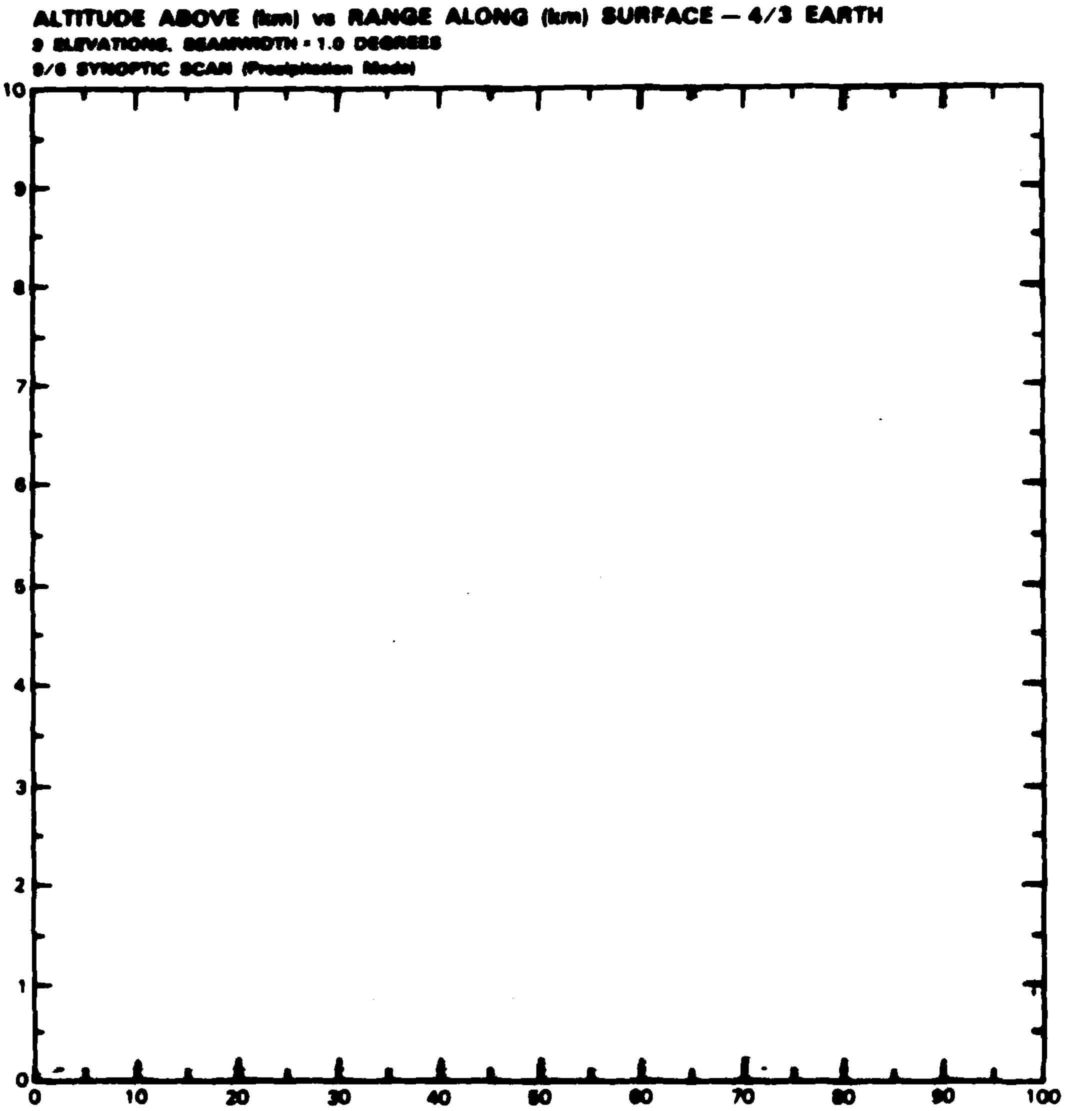


Figure V-2. Coverage provided by NEXRAD nominal scan strategy.

been principally in these areas that now are being de-emphasized, consequently we anticipate a reduction in the level of Lincoln participation in the RWG.

The two current RWG topics that Lincoln is investigating are:

(a) the operational utility of reflectivity base product data from a single low elevation tilt versus the high resolution composite reflectivity for CWSU assessment of data from a single NEXRAD, and

(b) the validity and operational utility of the NEXRAD turbulence product.

We plan to provide additional information on both of these topics to the RWG in the next reporting period.

VI. PLANNING FOR TDWR OPERATIONAL DEMONSTRATIONS

The FAA has requested that Lincoln and NCAR (with algorithm support from T. Fujita and NSSL) develop a joint program leading to an operational demonstration of the TDWR system concept including providing real-time TDWR products to ATC users (Tower and TRACON controllers and supervisors) in the 1987-90 time frame. Figure VI-1 shows the planned roles and responsibilities for hardware and products during operational evaluation. The upgraded FL-2 system will be used in a strawman automatic TDWR scan strategy and automatically in real time to:

(a) detect microbursts and provide estimates of their outflow spatial extent and severity,

(b) locate gust fronts and provide 20-minute estimates of arrival of the corresponding wind shift at the airport,

(c) generate volume estimates of high reflectivity and turbulence regions, and

(d) provide extrapolated storm position estimates in the initial demonstration*.

The detection algorithm outputs and corresponding controller products (e.g., a rectangle bounding the microburst divergent shear region such as shown in Figure IV-3) along with the (polar) base product data will be provided to an NCAR-developed rapid display system (RDS) as well as to a Lincoln Apollo workstation. A radar meteorologist at the RDS will:

(a) judge the meteorological corrections of the automatic algorithm detections (providing a product override if need be), and

(b) provide additional advanced products (e.g., locations of potential convective initiation) that do not yet have automatic detection algorithms.

Further review of the product outputs will occur at the airport control tower based on visual observations, pilot reports (PIREPS), and the low-level wind-shear alert (LLWSAS) system. The current plan is to hold the initial demonstration at Stapleton International Airport, Denver, Colorado, so as to take advantage of the scientific and operational community knowledge base developed during the JAWS (2) and CLAWS (4) programs.

Many details of the operational demonstrations need to be specified. This will occur in a series of Lincoln/NCAR/FAA meetings during the remainder of FY86.

A key area of initial focus is the development of adequate data sets for algorithm development and performance assessment. A two-day meeting was held at Lincoln in October 1985 to review the current status of the gust front and microburst algorithms and to discuss the

* The turbulence and storm position estimates are of lower priority than the other products. Subsequent demonstrations will utilize advanced products such as point predictions of microburst occurrence and regions where convection will commence in the near future.

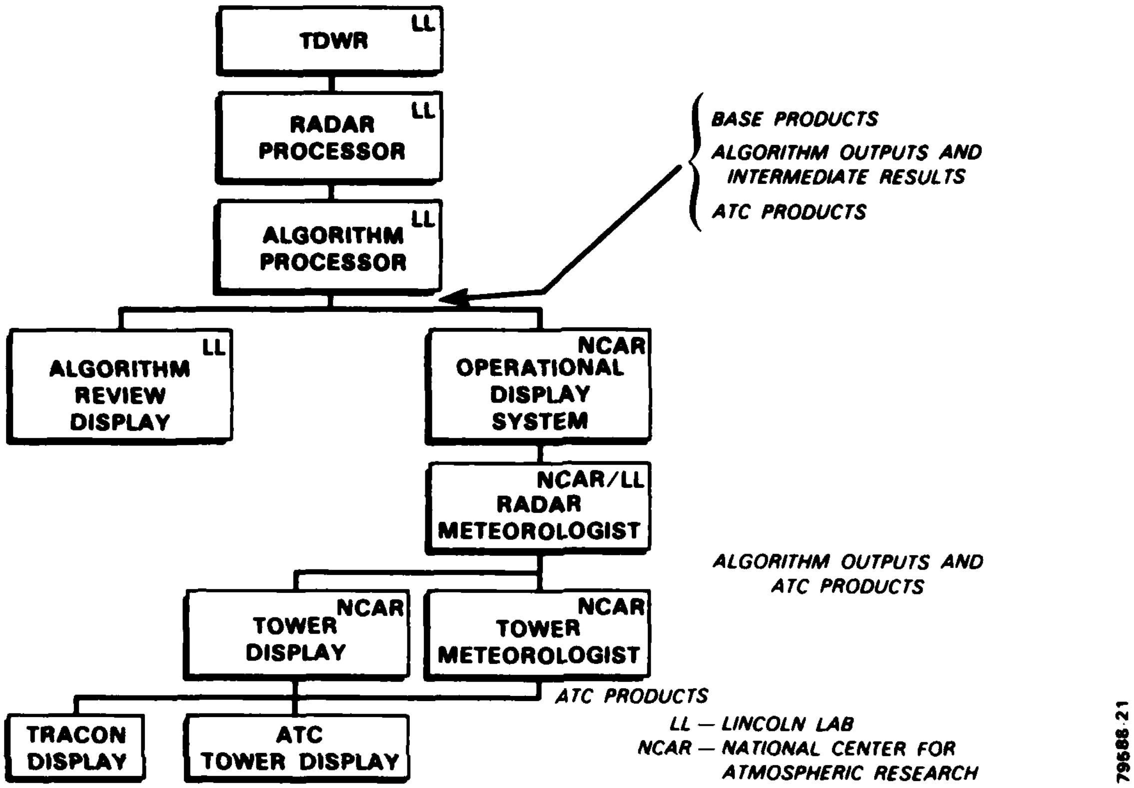


Figure VI-1. TDWR operational system architecture: 1988 operational test.

number and essential features of the test data sets. The organizations providing the data sets (Lincoln, NCAR, and NSSL) will be responsible for determining the 'truth' for the data sets that they provide. However, a joint group will develop objective criteria for each phenomena and there will be an independent 'truth' assessment of certain data sets for a fraction of data sets.

At a follow-up meeting held at NCAR in December 1985, progress in developing a better scientific understanding of microburst generation mechanisms was reviewed along with the status of the microburst and gust front detection algorithms. Action items from this meeting included:

(a) determining personnel who will participate in the product development activities of the TDWR users group (along with ATC users such as controllers and pilots),

(b) commencing planning for the 1986-87 experiments, and

(c) providing of microburst and gust front data sets from the 1985 FLOWS experiments in Memphis to NCAR and NSSL.

Subsequent meetings in Washington and Denver in March 1986 were held to commence the work program. The Lincoln and NCAR researchers concerned with wind-shear detection developed a plan for exchange storm data sets and analyses. A memorandum of understanding (MOM) between the Lincoln and NCAR groups will be developed in the next period and sent to the FAA for review.

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GLOSSARY

AGC	Automatic Gain Control
AGL	Above Ground Level
APU	Arithmetic Processing Unit
APU	Auxiliary Processing Unit
ATC	Air Traffic Control
CCT	Cross-Correlation Tracking
CFT	Common Radar Data Format Tape
CIDF	Lincoln Laboratory Common Instrument Data Format
CLAWS	Classify, Locate, and Avoid Wind Shear
CME	Clutter Map Editor
CNR	Clutter-to-Noise Ratio
COHMEX	Cooperative Huntsville Meterological Experiment
COHO	Coherent Local Oscillator
CPU	Central Processing Unit
CWP	Central Weather Processor
CWSU	Central Weather Service Unit
DAA	Data Acquisition and Analysis (Processor)
dBz	Unit of Weather Reflectivity
DCP	Data Collection Platform (implies transmitter to GOES satellite)
DIFAX	Digital Facsimile
FAA	Federal Aviation Administration
FIR	Finite Impulse Response
FLOWS	FAA/Lincoln Operational Weather Studies
FL-2	FAA/Lincoln Laboratory Test-Bed Doppler Radar
FMH	Federal Meteorological Handbook
GOES	Geostationary Operational Experimental Satellite
IOTF	Interim Operational Test Facility
JAWS	Joint Airport Weather Studies
LAN	Local-Area Network
LAWS	Low-Altitude Wind Shear
LLP	Lightning Location and Protection
LLWSAS	Low-Level Wind-Shear Alert System
MCM	Master Control Module
Mesonet	Refers to a network of automatic weather stations with a close, i.e., a 'mesoscale' spacing. Lincoln's spacing might be called 'microscale.'

MIST	Microburst and Severe Thunderstorm (Project)
MOM	Memorandum of Understanding
MPM	Multiport Memory
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research, Boulder, Colorado
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory, Norman, Oklahoma
NTR	NEXRAD Technical Requirement
NWS	National Weather Service
PAM	Portable Automated Mesonet
PE	Processing Element
P.E.	Perkin-Elmer
PID	Pulse Interference Detector
PIREPS	Pilot Reports
PPI	Plan Position Indicator
PRF	Pulse Repetition Frequency
P/SWS	Precipitation/Severe Weather Scan
PRT	Pulse Repetition Time
RDA	Radar Data Acquisition
RDS	Rapid Display System
RFI	Request for Information
RHI	Range Height Indicator
RPG	Radar Data Acquisition
RRWDS	Radar Remote Weather Display System
RTCP	Real-Time Control Program
RTS	Real-Time System
RWG	Radar Working Group
SCR	Signal-to-Clutter Ratio
SEM	Storm Extrapolation Map
SGP	Signal Gate Processing
SP	Signal Processor
SPACE	Satellite, Precipitation, and Cloud Experiment
TCP/IP	Transmission Control Protocol/Internet Protocol
TDWR	Terminal Doppler Weather Radar
UND	University of North Dakota
UNIX	'Generic' Operating System Developed by Bell Laboratories
WGE	Working Group E

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